THE No 1 UK MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

EPE EVERYDAY PRACTICAL ELECTRONICS

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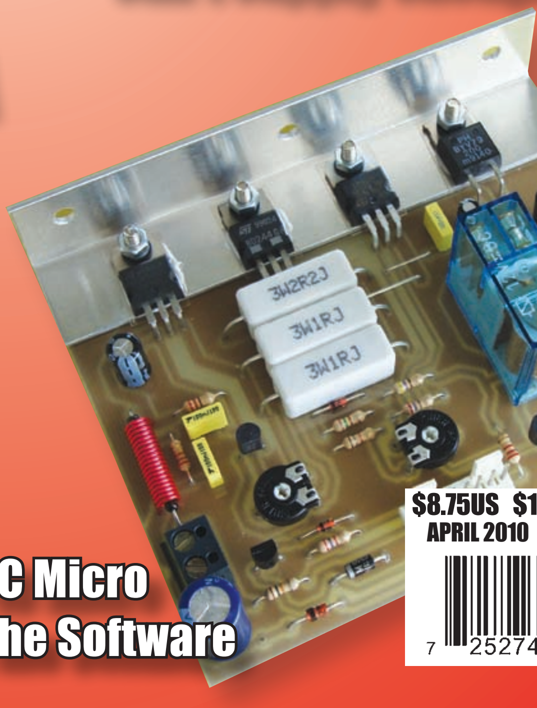

PLUS

TEACH-IN 2010

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Part 6 – Customising and Extending the Software

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APRIL 2010 PRINTED IN THE UK

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INCORPORATING ELECTRONICS TODAY INTERNATIONAL

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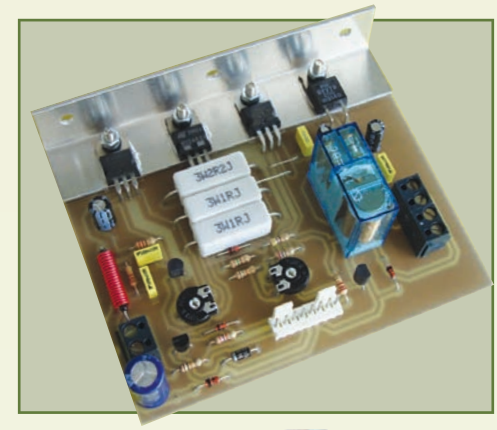

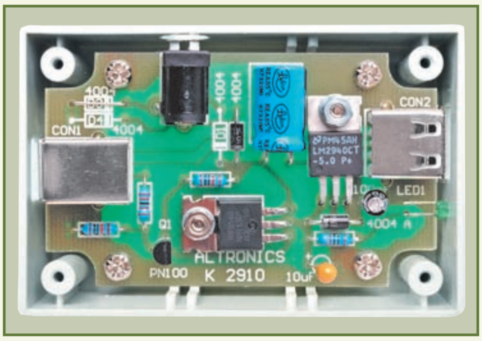

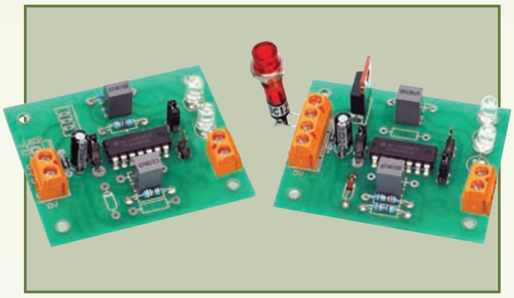

Our May 2010 issue will be published on Thursday 8 April 2010, see page 80 for details.

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74HC126	£0.46
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74HC139	£0.31
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74HC174	£0.27
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74HC241	£0.37
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74HC299	£0.61
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74HC373	£0.35
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74LS156	£0.36
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74LS158	£0.21
74LS160	£0.48
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74LS195	£0.24
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74LS241	£0.32
74LS243	£0.30
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74LS245	£0.45
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74LS257	£0.24
74LS258	£0.24
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74LS283	£0.47
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3A 400V	£0.40
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3A 1000V	£0.33
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6A 400V	£0.53
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2N3054	£0.85
2N3055	£0.82
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2N3440	£0.50
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2N3703	£0.10
2N3704	£0.11
2N3705	£0.08
2N3772	£1.72
2N3773	£1.91
2N3819	£0.20
2N3903	£0.11
2N3904	£0.05
2N3905	£0.10
2N3906	£0.08
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2N4403	£0.09
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BC108B	£0.14
BC108C	£0.18
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BC109C	£0.17
BC114	£0.19
BC115	£0.41
BC118	£0.41
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BC134	£0.36
BC135	£0.36
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BC238B	£0.11
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BC261B	£0.30
BC262B	£0.24
BC267B	£0.36
BC319C	£0.13
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BC479	£0.32
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BC517	£0.14
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BC547A	£0.09
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BC548B	£0.09
BC548C	£0.08
BC549B	£0.09
BC549C	£0.09
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BD284	£0.61
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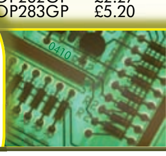

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A new way to read EPE?

The big IT story at the end of January was the launch of Apple's new box of tricks – the iPad. Apple being Apple, the iPad was revealed to be a sleek, beautifully designed object; and the launch was a slick event that was more showbiz than mere press launch.

Apple are an interesting company; although comparatively small as a computer manufacturer, they are very good at spotting future trends, taking existing ideas and adding their own particular design philosophy. Barely 18 months ago there was no such thing as an Apple mobile phone, but since its launch in the summer of 2007, their iPhone has transformed the mobile industry, with all the big manufacturers scrambling to produce their own versions.

So what is the iPad? Essentially it's a cross between a small netbook computer, a book reader such as Amazon's Kindle and the iPhone. One of the key uses highlighted for the iPad is reading on the go, from books, to newspapers and magazines such as EPE. This is particularly exciting for many newspapers because they are facing a real revenue crisis. Although the Internet contains much that is poor quality, there is still a very large amount of high quality news and comment available for free.

Why buy a newspaper when you can read it without paying on the web? Well, for many people, reading on the web means being tied to a desk or lugging a laptop around. Apple hope that with the convenience of their new machine, people may be tempted back to paying if the reading experience is sufficiently good. We will see, but I for one look forward to the opportunity of reading many copies of EPE on a train or away from my desk without a laptop or a bag full of heavy magazines!

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NEWS

A roundup of the latest Everyday News from the world of electronics

Nokia maps the world By Barry Fox

Nokia has rewritten the rules of walk-and-drive navigation by giving away the kind of mapping software that until now has had to be paid for. The latest version of Ovi Maps, based on turn-by-turn software and maps from Nokia-owned companies Gate5 and Navteq, is now available for free download into ten Nokia cell phones, with the pledge that from March all new GPS-enabled Nokia Symbian smartphones will come with the software pre-loaded.

The new free version of Ovi Maps will include all essential car and pedestrian navigation features, such as voice guidance for 74 countries in 46 languages, and traffic information for over 10 countries, as well as detailed maps for over 180 countries.

Hybrid system

The new system is hybrid; it can work without a data connection like a standalone satnav device, or connect by cell link to give live information, for instance on traffic or weather for five days, Facebook posting with shared location or access to Lonely Planet and Michelin travel guide information. Both drive and on-foot navigation is spoken as well as displayed, with paths and short cuts offered to walkers. Petrol stations, parking lots, theatres and restaurants can all be displayed at no cost. Speed camera mapping, as hitherto sold by satnav companies, comes free too.

Unveiling new Ovi in London, Anssi Vanjoki, Nokia's executive vice president, described free mapping as a 'game-changing milestone' and confirmed that the free service is now available across the US as well as Europe. Travellers will be able to download maps before journeying abroad to avoid high cell roaming charges, or sideload local maps by WiFi and PC to the device's cache, and so avoid any cell charges.

'You can turn off the data connection and still have the best personal navigation device money can buy' says Vanjoki.

Lower bandwidth

'The networks are on board' he said, 'because we are using vector graphics instead of bit mapping, which reduces the data to one tenth. Heavy use will not cause bandwidth congestion.'

Asked about the projected revenue stream from partners that earn through location advertising, Vanjoki said: 'The model is a little from a lot, rather than a lot from a little.'

'We are offering enhanced reality point and find. We own Navteq, who have the coordinates for everything; the best coordinates in the world. Add IP addresses to the coordinates and you have a platform that describes the world.'

'There was a lot of speculation about what product we would announce today. This is not a product launch, it is a major industrial announcement.'

Free to copy

Asked what Nokia was doing to stop third parties, for instance 'converting the free map data for use on a Blackberry', Vanjoki raised eyebrows with the clear blunt answer: 'If you want to, go ahead and do it'.

The first smartphones catered for include the Nokia N97 mini, Nokia 5800 XpressMusic and Nokia E72. More Nokia smartphones will be added soon. Current owners of Nokia smartphones that are compatible with the new Ovi Maps can download it free of charge from **www.nokia.com/maps**.

Bletchley celebrates 70 years of genius

In 2009, the 70th anniversary of the outbreak of World War II, the Bletchley Park Trust achieved a landmark conquest – for the first time ever it welcomed an amazing 100,000 visitors through its gates, providing vital income for the museum. This was a remarkable 30% increase on 2008 visitor numbers due to unprecedented media interest into some key national events involving Bletchley Park. This demonstrates that, at last, Bletchley Park is quite rightly becoming known as the 'national treasure' it is.

Funding secured

The most significant milestone of the year was the long-awaited announcement in September '09 that Bletchley Park Trust had secured a first-round pass, with the Heritage Lottery Fund (HLF) making available a development grant of £460,500 to be used to develop plans for transforming the venue into a world-class heritage and educational centre. Once the plans are complete and match-funding of £1,000,000 has been raised, the Trust will progress to the second stage of the HLF application process and apply for approximately £4.1 million to go towards the overall figure of £10 million that is needed for the whole development project.

The year commenced with a boost from actor and comedian, Stephen Fry, in Feb '09 urging his Twitter followers to support the campaign to preserve Bletchley Park. In March, Bletchley Park was announced in an online public vote as the building the nation was most proud of and the TV presenter, Tommy Walsh, visited the Park to present the award. The same month Milton Keynes Council, having gone to a public vote, announced they were to partner and match-fund the English Heritage pledge of £300,000 for essential repairs.

Veteran reunion

To help celebrate the 70th anniversary of the arrival of the Codebreakers at Bletchley Park in 1939, over 100 veterans attended the Annual Enigma Reunion weekend in September. One of the main attractions was a unique exhibition of rare Enigma and other cipher machines – the largest ever gathered together in one place. For some veterans, this was the first time they had seen the very machines whose codes they had helped to crack.

For visitor information, contact 01908 640404; **info@bletchleypark.org.uk**, or go to **www.bletchleypark.org.uk**.

BAN 'CHARGER CLUTTER'

A new product to help solve the problem of 'charger clutter' and reduce power consumption at the same time is the Universal Multi-Charger from One For All.

Most homes now have five or more portable devices. Each comes with a different charger that we leave plugged in at various locations round the house.

The Universal Multi-Charger will charge up to three devices simultaneously, with no messy wires and an LED light for the individual charge slots. Once each battery is fully charged, that slot shuts down automatically and the light goes out – so, as well as saving energy, you can tell the charging process is complete without having to check the device display (which is often locked).

It also uses turbo-charge technology to reduce the charging time. For example, to charge a Nokia 5200 phone from 0 to 100% using a standard charger would take 155 minutes. With the smart 'green' Universal Multi-Charger, it takes just 115 minutes: 25% faster. When no devices are charging, power consumption is less than 0.5W.

The One For All Universal Multi Charger works with mobile phones, MP3 players, PDAs, digital cameras, satnav, game players and other devices. Seven interchangeable tips are included in the pack for iPod/iPhone, Nokia, Sony Ericsson, MiniUSB (5-pin), LG, Samsung and MicroUSB.

Extra tips, and tips compatible with less popular devices, will be available online at: **www.oneforall.com/greenproducts**.

The charger is 'future-proof' too, as any new tips introduced for portable devices will be added to the online store.

The Universal Multi-Charger can be placed on a flat surface or mounted on a wall using the wall-mount plate included. The power cord is kept out of sight by winding it up in the bottom case.

To use, simply click the appropriate tip into one of the three slots and away you go. There are two further empty slots for storing tips you're not using.

The One For All Universal Multi-Charger is priced at £59.99.

Samsung Electronics begins mass producing 3D TV panels

Samsung Electronics has announced that it has become the first company to commence mass production of panels for 3D LED TVs and 3D LCD TVs.

'Recently, 3D displays have captured the industry spotlight,' said Wonkie Chang, president of the LCD Business at Samsung Electronics. 'Samsung aims to lead the global 3D TV panel market in pioneering panel mass production for 3D LED and LCD TVs.'

The company began producing LED and LCD compatible panels for 40-inch, 46-inch and 55-inch full-HD 3D TVs using '3D Active Glasses' this month, employing Samsung's true 240Hz technology. This delivers full-HD viewing in 2D, and also smooth, natural, full-HD 3D images that can vividly capture rapid movements.

By incorporating true 240Hz technology, operating at 240 frames per second, Samsung's panels deliver a more lifelike picture with alternating left and right eye images through the use of 3D Active Glasses technology.

Samsung has reduced the response time of its LCD and LED panels by 20% to less than four milliseconds, eliminating any interference between left and right eye images. With this improved response time, Samsung claim it is able to achieve natural 3D images and also deliver 2D pictures, capturing rapid movement with exceptional clarity.

The system's new 3D Active Glasses technology first blocks the left and then right lens, causing a momentary lag when images are shown to each eye to achieve more lifelike 3D images. (The term, '3D Active Glasses,' was selected as an official term by the Glasses Standardization Working Group of the Consumer Electronics Association (CEA) earlier this year.)

The polarised glass method previously used in 3D glasses produced separate images for the left and right eyes, resulting in half the resolution of two-dimensional pictures as only half of the screen can be viewed through each polarised filter. Brightness was also lowered because of the polarising filter.

According to a market research firm, DisplaySearch, the 3D display market is expected to grow from $902 million in 2008 to $22 billion in 2018. Specifically, the 3D TV market is expected to expand to a $17-billion market, with sales increasing from 200,000 units in 2009 to 64 million units 2018.

Self-programmable Flash memory from Microchip

Microchip has introduced a new member of its 8- and 14-pin PIC16F61X 8-bit PIC microcontroller (MCU) family, targeting cost-effective general-purpose applications. The PIC12F617 MCU features 3.5kbyte of self-programmable Flash program memory, and peripherals such as a 10-bit ADC – all in a miniature 3mm x 3mm package.

It is a low-cost alternative to EEPROM and is useful when an application requires remote updates, or the ability to store system data or look-up tables. The microcontroller features an 8MHz internal oscillator and an on-chip 4-channel 10-bit ADC, a comparator with hysteresis and a PWM with complementary outputs. It provides a framework for applications such as LED lighting control, motor control and capacitive touch keys.

An Alternative 12V 10A Power Supply

By Ken Ginn

An unusual and useful take on power supplies. It can even keep going if there's a mains failure

A GOOD few years ago I designed a 12V, 15A power supply, which, at the time, was considered a unique design. The idea was very successful, and was used to power a set of three 'packet radio' transceivers, running twenty four hours a day, seven days a week.

The idea around this power supply was to build a unit that is fed by a low current source, in the order of 3A, and provide a peak current of about five times higher than this; at 15A. Fifteen amps was sufficient to provide power to all three radios in use, should they all transmit simultaneously.

Packet radio usually has a low-duty transmit cycle, where the equipment sits idle, listening for other radio nodes for a very long time, occasionally transmitting. The additional current supplied to the radios over and above the 3A supply (the primary mains derived source), is taken from a reservoir; a gel-cell battery.

Although the power supply was originally designed to run packet radio transceivers, the unit is not just confined to this type of radio. In fact, any radio can be used with this power supply. It can also be used as a main source of power; ie the battery, or used as a standby source of power in the event of a power failure. There would be a float charge for the battery when mains voltage is applied, and the battery can be relied on to supply current to equipment when the mains supply fails.

Charging up

The battery, during low current demand, is float-charged. The mains derived power supply is rated to deliver a low current, a minimum of 3A. Any current drawn above 3A and the supply goes into current limit, and the remaining current demand is supplied by the gel-cell battery. This does, of course, mean that when the transceiver switches back into receive mode, the batteries charge is then topped up from the mains-derived power supply. Thereby topping up any charge lost during the time the transmitter was keyed up.

The rate at which the battery replenishes its lost charge depends upon a number of factors; these include the quiescent current drawn by the radio(s) during receive, and the charging-current limit set by the power supply circuit. Since the current limit will deliver the maximum current supplied, that is 3A.

The charging current will depend upon the value of current the radio takes in receive mode. For example, if the maximum current is 3A, and the quiescent current of the radio is 200mA, the maximum available current for charging will be 2.8A. The float-charging current will reduce as the battery voltage rises and will settle down to less than 50mA when the battery is in a good state of charge.

Input supply

The input power supplied to the unit (18V to 25V DC) is either provided by a mains transformer, bridge rectifier and smoothing capacitor arrangement within the power supply's enclosure;

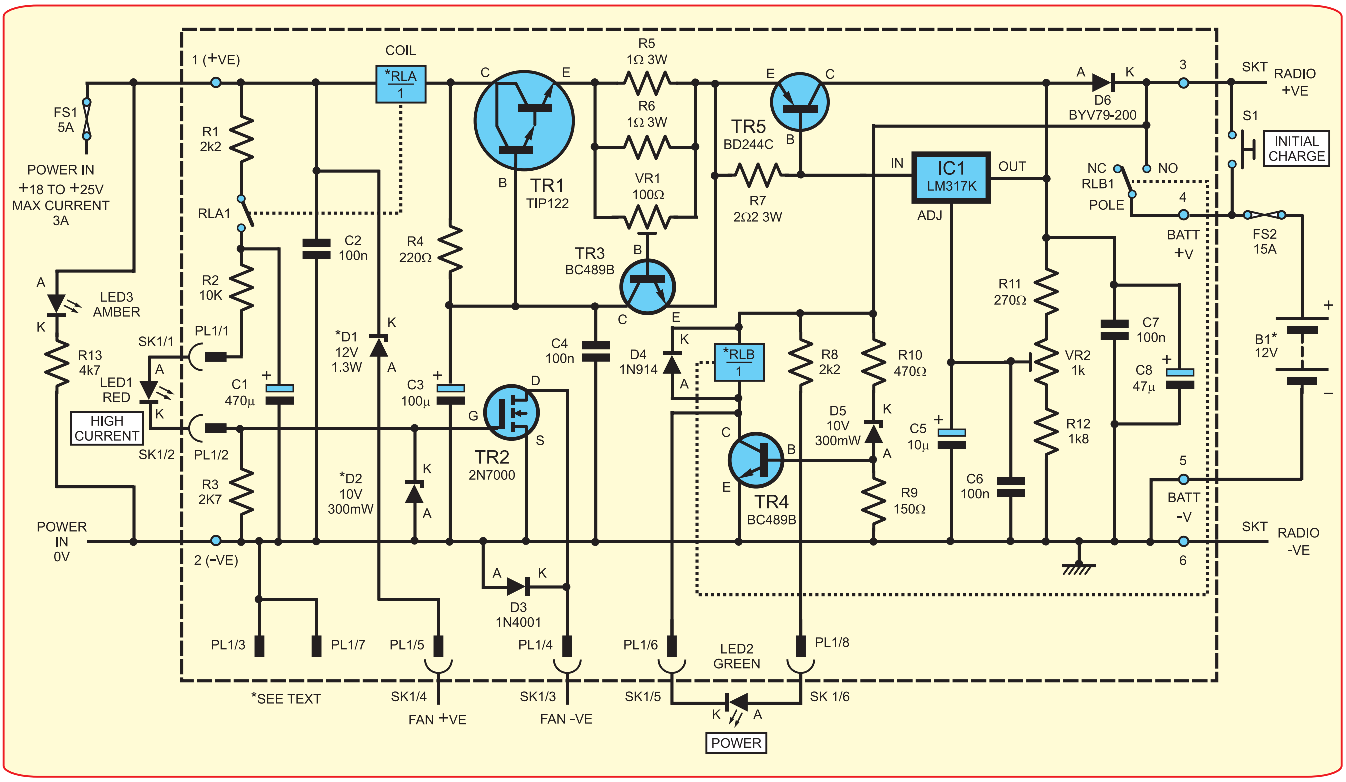


Fig.1. Complete circuit diagram for the Alternative 12V 10A Power Supply

or, as shown in this particular design, a separate external unit – a switched-mode PSU. Having a ready-made primary power supply avoids the problem of handling components that will be passing mains voltages and current, a useful safety aspect of the design.

Circuit details

The full circuit diagram for the Alternative 12V 10A Power Supply is shown in Fig.1, and includes the major components mounted on a PCB. Power of about 18V to 25V is applied to screw terminals pins 1 (+V) and 2 (–V) on the circuit board.

The input current to the circuit is limited by a 5A fuse (FS1) for protection purposes. Relay RLA is a small 'homemade' reed type that is set to close the contacts when the current drawn through this relay coil is in the order of about 1.5A. When this occurs, RLA's contacts close, current is drawn through resistor R1, LED1, R2 and onto R3. The voltage across resistor R3 is sufficient to turn on FET TR2, which supplies power to a 12V cooling fan.

Capacitor C1 in the circuit forms a timing function, where a delay of about one second is experienced at switch on, and about five seconds at switch off. This was designed so as to yield a degree of hysteresis should the power supply be used to supply a radio transmitter sending Morse code (CW).

It was thought best not to modulate the power supply fan to the tune of the Morse code being sent. This could be distracting.

Zener diode D2 limits the gate/source voltage of TR2 to 2.7V. Field effect transistor TR2 is used to switch a cooling fan on in order to cool the circuit down during high and prolonged current demand. A 1.3W 6.2V Zener diode (D1) is selected for an 18V input, or 12V for a 25V input. The Zener diode can be removed and a shorting link replace it if a 24V fan is used. An old redundant computer fan was used in the prototype to assist in the units cooling. When the reed relay contacts of RLA1 are closed, LED1 is illuminated to indicate that a current higher than 1.5A is being drawn from the mains derived power supply, and cooling is being effected.

Voltage regulation

Transistors TR1, TR3, TR5 and IC1 form a voltage regulator that is commonly seen in power supplies. TR1 is a Darlington *NPN* transistor with a high current gain that acts with TR3. These two transistors act with resistor R4 and the parallel resistors R5 and R6 to form a current limit device.

The preset potentiometer VR1 is used to set the current limit value, when there is 0.7V across the base/emitter junction of TR3. In the prototype the current limit was set to 3A.

During a current limit condition (usually a fault condition in a conventional series-regulated power supply), the circuit can become somewhat unstable. To increase the stability of the circuit, a 100µF electrolytic capacitor (C3) is included to smooth the supply to the base (B) of transistor TR1. In addition a 100nF capacitor (C4) is added in parallel with C3.

Transistor TR5 and IC1 act together as a high current voltage regulator. Including R7 and TR5 increases the current handling of IC1, which, on its own, is limited to 1.0A. Choosing a value of 1Ω for R6 ensures that TR3 bypasses current around IC1 which is set at approximately 450mA, less than half the maximum current handling of this device, IC1.

Charging circuit

Diode D6 provides isolation between the battery and the charging circuit. Should the mains supply fail for any reason, this diode inhibits the battery from discharging through the charging circuit. Transistor TR4 supplies current to the relay coil RLB, which is then energised and hence the relay contacts are closed. The battery can now be charged and utilised in the power supply.

In the base circuit of TR4 is a 10V Zener diode (D5), this simple arrangement ensures the transistor

Parts List – Alternative 12V 10A Power Supply

1 PC board, code 751, available from the *EPE PCB Service*, sizes 108mm × 89mm
1 diecast aluminium box
1 12V, 7AH to 24AH gel-cell battery (Yuasa – see text)
1 reed relay – see text (RLA)
1 12V PCB-mounting relay – see text (RLB), (example, Maplin (12V 6A) stock no FJ43W or Rapidonline (12V 16A) stock no. 60-10105)
1 chassis-mounting battery plug and matching battery cable socket
2 3-pin XLR connectors
1 2-way screw terminal block
1 4-way screw terminal block
1 8-way keyed PCB pin-header and matching cable socket
1 3A pushbutton switch, push-to-make
1 cooling fan (100mA max.) – see text
4 TO220 insulating kits for TR1, TR5, IC1 and D6
1 5A fuse and panel-mounting fuseholder (FS1)
1 15A fuse and panel-mounting fuseholder (FS2)

Piece of L-shaped 1.5mm aluminium for heatsink/board mounting strip; 1.0mm dia. enamelled copper wire for reed relay (approx. 18½ turns) coil – see text; 5A and 15A heavy-duty connecting cable (auto-cable) – see text; spade terminals (3 off) plus serrated lock washer for chassis earth (0V) point; fixing nuts and screws; heatsink paste.

Semiconductors
1 12V 1.3W Zener diode (for 12V 100mA max. fan – see text) (D1)
1 10V 300mW Zener diode (D2)
1 1N4001 1A 50V rect. diode (D3)
1 1N914 signal diode (D4)
1 10V 300mW Zener diode (D5)
1 BYV79-200 diode (TO220 type) (D6)
1 TIP122 *NPN* power Darlington transistor (TR1)
1 2N7000 *N*-channel FET (TR2)
2 BC489B *NPN* transistors or equivalent (TR3, TR4)
1 BD244C *PNP* power transistor (TR5)
1 LM317K 1A variable voltage regulator (IC1)
1 3mm red LED (LED1)
1 3mm green LED (LED2)
1 3mm amber LED (LED3)

Capacitors
1 470μF 35V radial elect. (C1)
1 100μF 35V radial elect. (C3)
1 47μF 35V radial elect. (C8)
1 10μF 35V radial elect. (C5)
4 100nF 63V polyester (C2, C4, C6, C7)

Resistors (All 0.25W 1% carbon film, except where stated)
2 1Ω 3W wirewound (R5, R6)
1 2Ω2 3W wirewound (R7)
1 150Ω (R9)
1 220Ω (R4)
1 270Ω (R11)
1 470Ω (R10)
1 1k8 (R12)
2 2k2 (R1, R8)
1 2k7 (R3)
1 4k7 (R13)
1 10k (R2)

Potentiometers
1 100Ω horizontal preset (VR1)
1 1k horizontal preset (VR2)

is turned on when mains power is applied and the units output voltage is above 10.7V. Hence, relay RLB is energised when the mains supply is connected or the battery is showing a healthy state of charge. This occurs when the output from the regulator (IC1) is above 10.7V. This also ensures the voltage at the battery is sufficient to power the radio in the event of a mains failure.

Once the battery voltage drops below about 10.7V, relay RLB1 contacts will open; disconnecting the battery from the radio circuit. This ensures that should the mains power fail and the radio relies on power solely from the battery, the battery is not over discharged in this circumstance, which could cause possible damage to the battery. When the relay is energised, LED2 will also be illuminated, indicating a good supply to the radio.

Charging of gel-cell batteries

The technique for charging gel-cell batteries uses a constant-voltage, current-limited system. The constant voltage is generated and set to a specific value, and for a 12V battery it's 13.2V (2.275V per cell) – (Yuasa gel-cell, NP12-12 series – 12V, 12AH).

The maximum charging current should be set to one quarter of the batteries AH (amp/hour) capacity. For a 12AH battery, this would equate to 3A. The maximum charging current could be set lower, however the battery will take a little longer to reach its full capacity after a deep discharge.

Should a deeply discharged battery be attached to this power supply, the battery could take a very large current at switch on, and the output of the power supply could drop severely. The charging current will limit at the value determined by preset VR1, and the battery should slowly rise to a value around 12V within minutes.

It is stressed that the charging voltage and the charging current *must not* be set too high, and the constructor is urged to seek the battery manufacturer's data sheets for float charging their specific battery. As mentioned, the float charging of the battery at 13.2V is derived from Yuasa data sheets. Failure to do so could result in premature failure and possible rupture of the battery due to excessive out gassing during float charging.

Reed relay

Reed relay RLA's coil is fabricated with approx. 18½ turns of 1.5mm enamelled copper wire wound on a 3.5mm drill; the drill is used as a mandrel, or coil former. The coil leads are formed to fit the PCB – see Fig.2, Fig.3. and board photograph. The coil is an air wound type, 18½ turns closely wound with an internal diameter of 3.5mm.

The glass-encapsulated 'reed' insert (contacts) is set centrally within the coil, and should have an actuating current of approximately 1.5A. In the prototype, a rubber sleeve was positioned around the reed to help space it and keep it centrally mounted within the assembly.

Construction

The printed circuit board (PCB) component layout and full-size underside copper foil master pattern are shown in Fig.3. This board is available from the *EPE PCB Service*, code 751.

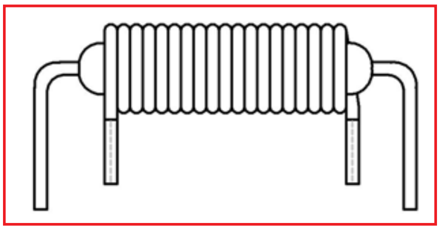


Fig.2. Construction and assembly of reed relay (RLA) coil. Using 1.0mm dia. enamelled copper wire, you need to wind approximately 18½ turns of wire on a 3.5mm dia. former (ie drill shank). The coil is removed and then slid over the glass-encapsulated relay. The coil ends and relay leads are then formed to fit into the PCB

The interwiring details between the board and case-mounted components is shown in Fig.4 and accompanying photographs.

Most of the components are soldered onto the PCB. Make sure there are no dry joints or solder bridges shorting out adjacent copper tracks. Observe the polarity of any of the polarised components: diodes, transistors and electrolytic capacitors.

The semiconductor power devices are attached to a small L-shaped aluminium bracket, which is attached to one side-wall of the casing of the diecast box that completes the unit. These power devices are mounted with the usual TO220 mounting kits: mica washers and plastic insulators, with an M3 screw and nut arrangement. Using heatsink compound will further help conduct the heat away from these power devices.

While mounting these devices, check with a multimeter the resistance between the device pinout (base, emitter, collector, anode or cathode) leads to the heatsink. Check to see if there is a short circuit; if found rectify the fault before continuing. Occasionally, a piece of swarf from the hole drilled in the aluminium heatsink/mounting bracket pierces through the insulation washer, causing a short between the heatsink and the tab of the component.

The unit is housed in an aluminium diecast box, and forms part of the heatsinking arrangements for the circuit. The majority of the components are mounted on the PCB. Most of the components dissipating heat are electrically isolated with mica washers and paste, and attached to the aluminium mounting bracket. This bracket, made from 1.5mm aluminium sheet, is attached to the diecast box, and will draw away the heat from these components to the outer casing.

Resistors R5 to R7 are all 3W wirewound types, and should be mounted slightly proud of the PCB, to allow cooling air to pass around them. The power ratings of these components are well over-rated for their application here, and R5 and R6 will each dissipate about 2W, with a current drawn from the primary source of 3A. These two resistors will get hot in use at these currents. The fan in the unit, which is actuated when relay contacts RLA1 close, will cool these components down and also the other components as well. Resistor R7 will certainly dissipate less than 200mW when the maximum limiting current is drawn.

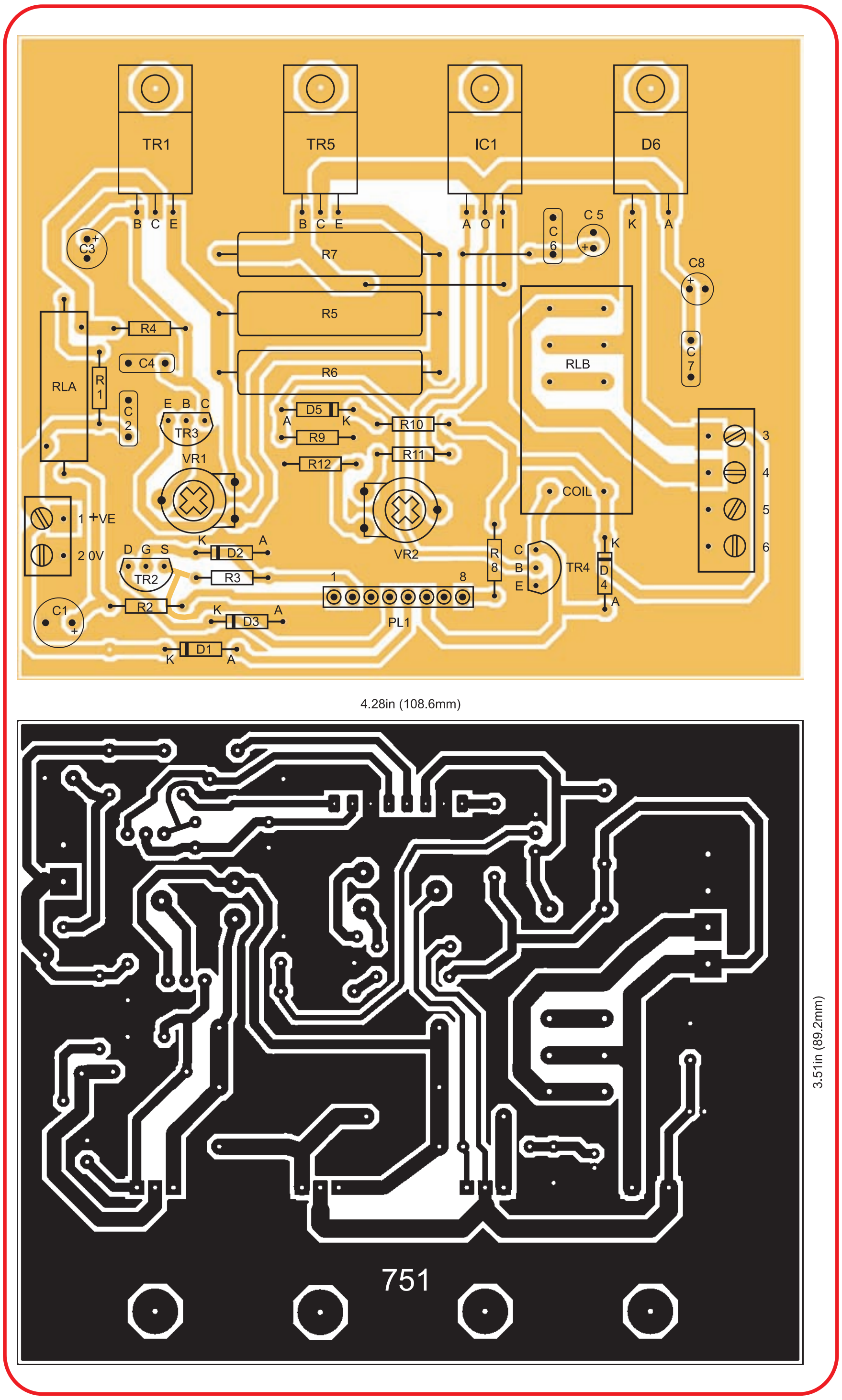


Fig.3. Printed circuit board component layout and full-size copper foil master. The L-shaped aluminium heatsink/mounting bracket is not shown here – see photos

Against convention

Details of the interwiring between the circuit board and off-board components is shown in Fig.4. Note resistor R13 and LED are located off the PCB and provide a power on indication.

Going against convention, where power supplied to a circuit is generally supplied via a socket. In this project 3-pin XLR connectors have been used. The output to the battery has a chassis-mounted plug, and the battery a cable socket.

This is deliberate, as it was considered that should anything accidently short across a socket, it would be preferable if it shorted across the lowest current source, ie, the power supply. The higher source of power, a gel-cell battery could deliver well over 100A if the terminals are shorted across, and explode as a consequence. The power supply current, even under a short circuit condition, is set by VR1 to 3A.

The connecting wire and connectors on the input supply, and from the output of the circuit, ***must*** be adequately rated for the current drawn. The prototype used 5A wire on the input and 25A connecting wire on the output side.

Relay

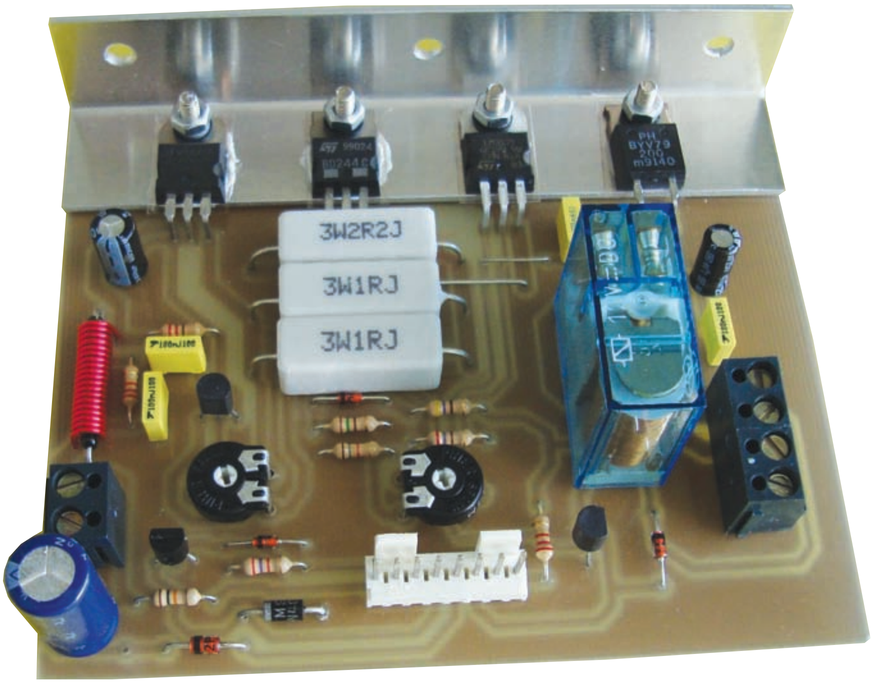
The choice of the output relay RLB really limits the current-handling capacity of the power supply, since its contacts will be passing the full load current. The footprint of the relay on the PCB provides a choice of contacts available from DPDT to SPDT, with contact ratings up to 15A in SPDT arrangement, which would be suitable.

In the prototype, a DPDT relay was used and was found to be adequate in passing the 10A which the unit was designed to supply. It must be stressed that the PCB copper tracks carrying this level of current ***must be built up with solder*** to reduce the track resistance, and hence the track current carrying capacity.

Ventilation is an issue here, and the cooling fan is mounted on the base of the unit to draw cool air into the case, and an additional set of holes need to be drilled in the case to vent the warm air. A fan-guard was used to protect the fan and any fingers from getting caught in the fan blades. Mounting feet have to be of sufficient height as to clear the fan guards and allow an adequate flow of air into and out of the case.

Checking the unit

Before the assembled PCB is mounted in the finished enclosure, visually check all the solder joints. Check also the orientation of all the polarity dependant components. A simple check now could stop a lot of heartache later.



The completed circuit board showing the heatsink bolted in position

With a multimeter, check the resistance between pin 1 and 2, 5 and 4, and 5 and 3 on the PCB. The readings in all three cases should read above 1kΩ. If a reading is found to be lower, look for shorts or other problems on the PCB.

While checking the unit, it is wise if a current-limited power supply is not to hand, to power the unit with an 18V supply via a 47Ω high power resistor (25W) and a series ammeter monitoring the input current. If a fault occurs, the test resistor will limit any current drawn during testing and limit any damage to the circuit which a fault may otherwise cause. If there is a fault, it may get very hot – so beware!

Setting up

For the initial setting up, include the 47Ω 'test' resistor. If not, a current limited power supply supplying 18V to 25V could always be used, with a current limit initially set to 100mA.

Ensure the preset pots VR1 and VR2 are both set fully anti-clockwise. This will ensure that the current limit is set to the minimum value, and the output

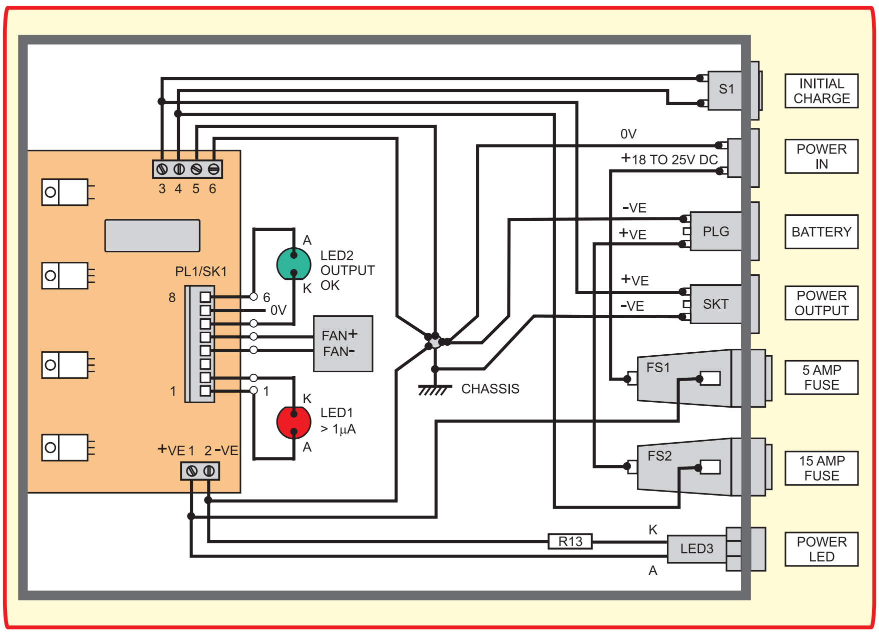
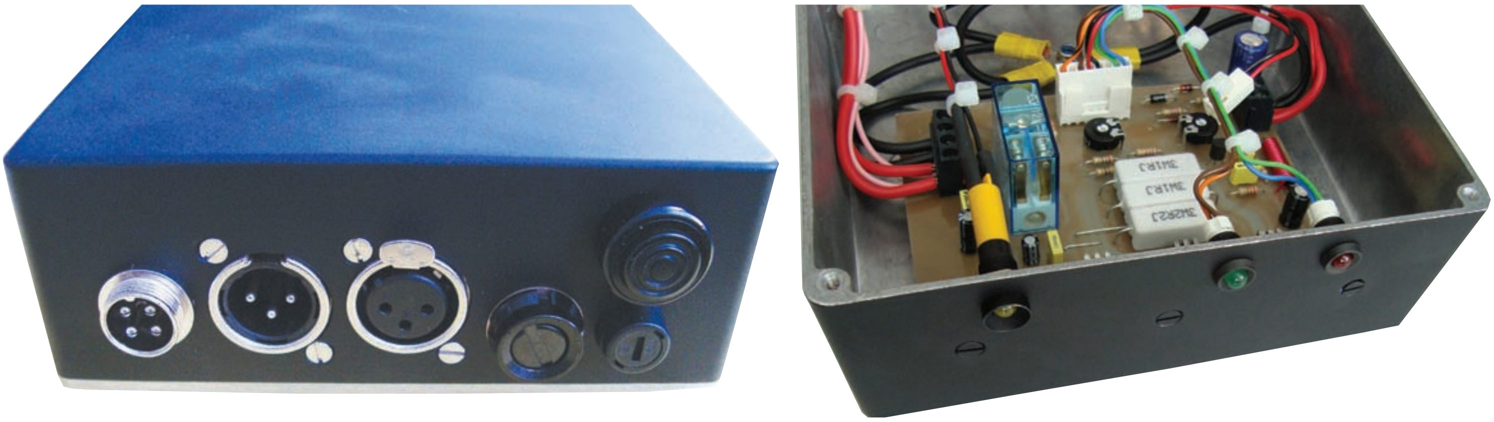


Fig.4. Interwiring to off-board components. The connecting wire and connectors on the input supply and from the output must be adequately rated for the current drawn – see photo opposite



General layout of components mounted on the rear (left) and front (right) of the completed unit

voltage is set to maximum. Setting the output voltage to maximum will ensure that contacts RLB1 are closed.

No equipment or battery should at this point be connected to the circuit. Wait until it has been fully tested and the output voltage set to the nominal output voltage of 13.2V to 13.6V.

As a temporary measure, connect a pushbutton switch between pins 3 and 4 on the circuit board, and hold the pushbutton down as you adjust the output voltage until the relay contacts of RLB close. The output voltage of the circuit is adjusted with the aid of VR2 and is set to 13.2V. The output voltage is measured across terminals 3 and 6 on the circuit board.

Connect up the circuit supplying current to the power supply unit, slowly increasing the input voltage set to 18V (using a bench power supply and a 47Ω series test resistor), and constantly monitor the current at this point. The current drawn should be in the order of 123mA with the relay RLB energised. At this point LED2 should be illuminated and LED1 extinguished. The output voltage is monitored with a DVM and set to 13.2V for a 6-cell gel-cell battery (float charging the battery at 2.275V per cell) as VR2 is adjusted).

The charging current is set by the manufacturer, and can, as a general rule of thumb, be set to a maximum current of one quarter of the maximum amp/hour (AH) capacity of the battery. For example, a 12AH battery can be charged at a maximum current of 3A. This is the current limit value set by the unit, using trimpot VR1. Setting preset VR1 to the 11 o'clock position will set the current limit (maximum charging current) to 3A. Y o'clock – 2.5 amps, and w o'clock – 2.0 amps.

Limiting current

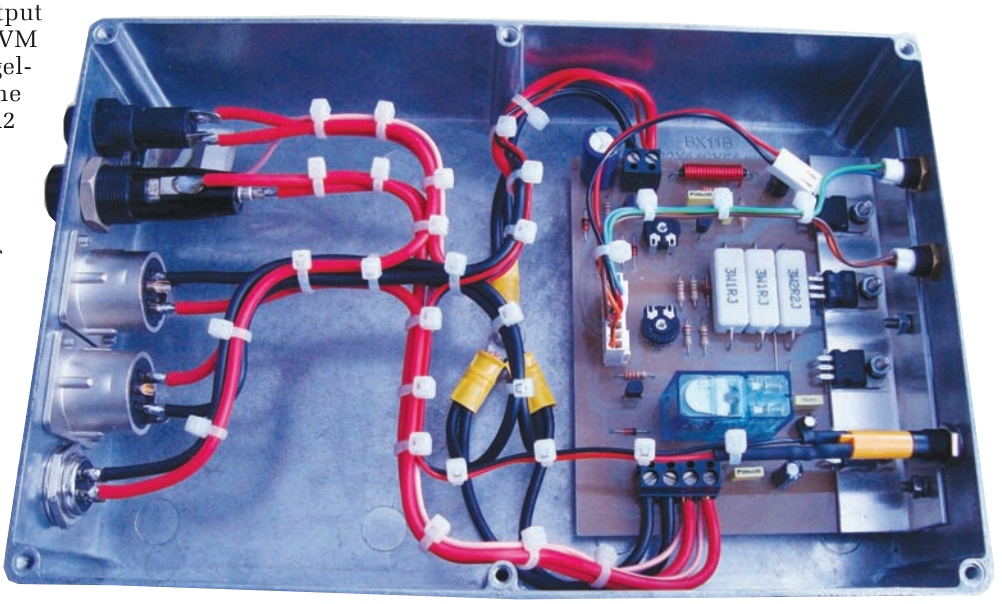
To set the limiting current accurately, a discharged battery could be connected in circuit, in which case the 47Ω test resistor (if used) would have to be removed from the input side of the power supply. Monitor the current drawn by the circuit using an ammeter and set the current by adjusting VR1 to match the battery used. ***Important: Do not set the charging current too high, as this will cause premature failure of the battery***.

If a discharged battery is attached to the power supply, the voltage at the battery may be low and hence the charging circuit voltage. The battery voltage will depend upon the state of charge, low enough to want to draw the power supplies limiting current. In this case, an ammeter on the input side can be used to read this current.

Adjusting VR1 will adjust the current limit of the circuit and hence the maximum charging current for the battery. As mentioned earlier, the maximum value for this current will actually be dependant on the capacity of the battery. A larger capacity battery can, of course, be used, but from a deep discharge will take longer to reach a full charge.

In use

The power supply has been very successful in use with the homebase station radios, and no appreciable problems with 12AH and 24AH batteries. It has to be remembered that the power supply has to be left on after use to top up the battery; leaving it on overnight should not be a problem. ***EPE***



Internal view of the completed power supply. The 'loose' pin header in the top-right corner connects to the base (lid) - mounted salvaged computer fan

EPE EXCLUSIVE

Win a Microchip mTouch AR1000 Development Kit!

EVERYDAY PRACTICAL ELECTRONICS is offering its readers the chance to win one of four mTouch AR1000 Development Kits from Microchip. The kit provides everything designers need to get started using AR1000 resistive controllers and includes the AR1000 development board, a seven-inch four-wire resistive touch screen, a PICkit Serial Analyzer and all the necessary interface cables, as well as a CD containing technical documentation and all the necessary software. The CD also includes an easy-to-use AR1000 configuration utility, which has a graphical user interface (GUI) that enables designers to test all user-configurable options with the AR1000 controllers.

The AR1000 controllers eliminate trial-and-error engineering by providing sophisticated, proprietary touch-screen decoding algorithms that enable applications to receive fully processed, reliable touch coordinates. Combining Microchip's capabilities in microcontroller manufacturing with the recently acquired Hampshire Company's 15+ years of experience designing resistive touch-screen controllers, the AR1000 controllers enable low-risk product development, lower total system cost and shorter time to market for embedded resistive-touch designs. Popular due to its low cost, acceptance of finger, glove or stylus-pen inputs, and overall ease of manufacturing and integration, resistive touch-sensing technology is suitable for applications such as mobile phones, industrial automation, retail point-of-sale, gaming/entertainment, and automobile navigation systems.

The AR1000 controllers provide universal 4-, 5- and 8-wire support, as well as support for SPI, I²C and UART communication interfaces, and are available in 20-pin QFN, SOIC and SSOP packages.

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TechnoTalk

Unreported News

Mark Nelson

Stories that don't hit the headlines are this month's theme. Sure, they might not interest mass audiences, but for electronicists they make fascinating reading. See if you agree, as Mark Nelson sets out a selection of stories that have a bearing on our electronic lives.

I'm a voracious reader, almost to the point of obsession. However, reading is not my only passion; I cannot resist sharing my discoveries with others, as you are about to find out.

Did you know that optical fibres can be used for security purposes, or that our government jams satnav systems? And are you aware that Internet service providers are now using 'deep packet inspection' to identify bandwidth hoggers? Maybe not, so read on!

Anti-insurgence

The next war will not necessarily be fought on the beaches or in the air. Instead, the attacks that might bring down our daily routine will be on infrastructure. If our enemies succeed in paralysing the banking system and our transport, power and telecomms networks, we won't be able to go to work, the shops will run empty and we won't be able to pay for anything. A dozen or so strategically placed bombs could take out the main network control centres and key points in the datacomms network, making 'due functioning' (carrying on as normal) extremely difficult. If you also factor in the threat of cyber-warfare (mass denial of service attacks on important websites and servers) we could be mightily vulnerable.

This need not come to pass if we take appropriate precautions, and while you and I may have no idea what kind of protective measures are in place, we can get some indications from snippets turning up here and there. Last autumn, the trade paper *Land Mobile* reported that the Ministry of Defence had given notice of a series of GPS (satnav) jamming exercises taking place at sea off South Shields. Jamming was taking place in two one-hour slots per day in November and December.

Of course, it's long been known that the US government could turn off GPS at will, which is why the European Commission has invested around five billion euros in the alternative *Galileo* satellite system. This will not only provide satnav, but also search and rescue facilities. The fourteen satellites of *Galileo* are due to become operational in early 2014.

OptaSense

The name OptaSense is what QinetiQ (born out of the UK's Defence Research Agency) has given to an ingenious technology that turns fibre-optic cables into acoustic security sensors. What QinetiQ, now an international defence and security technology company, has done, is to detect multiple, simultaneous disturbances with precision over a 40km length of existing or installed optical fibre.

OptaSense has many applications, and here are just a couple. Consider border and perimeter security; anyone climbing, cutting or digging near the perimeter disturbs the fibre and generates an alarm. The OptaSense system then classifies the disturbance, provides the coordinates and cues other sensors, such as cameras, to ensure the operator instigates the appropriate response. Or imagine protecting a long-distance datacomms cable, or a fuel pipeline; the approach of a digger or the lifting of a manhole cover will generate an alarm. The system's acoustic sensitivity can also be used to listen to the flow through a pipe, so that blockages and leaks can be located.

The fibre optic technology behind OptaSense has been developed by Sensoptics Ltd, another UK-based company. QinetiQ has provided the systems integration and marketing inputs. The system, which is simple to install and operate, combines standard single mode optical fibre with control and analysis software that continuously monitors the entire fibre to detect, locate and categorise multiple, simultaneous disturbances. The user interface displays the cause of the disturbance and alarms overlaid on a map, plan or aerial photograph to provide a clear visual indication of the position of the incident. Although the press launch took place only in 2007, the technology had already been employed by security services for ten years or more.

Deep digging

Like me, you probably curse loudly whenever the Internet slows down to a crawl and websites take ages to load. On the average domestic broadband connection, the cause is probably contention (see **http://usertools.plus.net/tutorials/id/11** and **www.servicesat.net/internetspeedsan.html**).

Contention is the result of sharing an Internet feed with other users, and if one of these is constantly involved in movie downloads, peer-to-peer (P2P) file sharing, multi-player gaming or other bandwidth-intensive applications, your share of the Internet is going to look pretty shabby. The problem is bad enough on domestic broadband connections, but is even worse on mobile broadband services, where users are demanding reductions on their subscriptions if they don't get the level of service they have paid for.

Internet Service Providers (ISPs) naturally take a pretty dim view of people who hog all the bandwidth and accuse them of abusing the 'fair use' agreements. However, before the ISPs can take action against these cheats they have to identify the perpetrators and that's not always easy. The applications that devour unfairly excessive bandwidth generally use port-hopping, encryption, masking or other techniques to hide their identity, so the ISPs need to dig deep to uncover the identities of the people.

The solution, according to Continuous Computing, an American hardware and software provider, is 'deep packet inspection (DPI)'. According to co-founder and chief technology officer Mike Coward, DPI offers the ability to inspect each packet, classify it as part of a flow, and then inspect the flow to determine application, subscriber and content provider. Once this is done, operators can apply different policies to individual flows based on subscriber profile, application, time of day, or network loading. These policies can include prioritising one traffic flow over other flows, dropping a flow, or rerouting the flow.

Battle is declared

Several ISPs started rolling out new 'traffic shaping' software using DPI a couple of years back, throttling down torrent speeds to a crawl in some cases. The technique can be very effective, and subscribers report a new data rate of 5kbit/s compared to 700kbit/s previously. Some applications (such as Skype) encrypt their traffic, so DPI will not help the ISPs in this case.

The subject is, nevertheless, an ethical minefield, both on user privacy grounds and net neutrality (the need to treat all internet traffic equally). The 'abusers' are not beaten yet, however. Apparently *Tuoto*, a Chinese torrent and eMule client, has managed to bypass DPI, giving back regular speeds for torrent downloads.

Finally, every Internet user runs a remote but real risk of being wrongly accused of illegal file sharing. A free download will tell you everything you need to know to understand your legal position if you receive a 'nastygram' from an intermediary acting for rights holders.

The document explains the way that 'speculative invoicing' takes place to users suspected (or wrongly identified) of file sharing, with demands of £500 in lieu of further legal action. The report claims that in November 2009 some 25 thousand British Telecom broadband users were identified as file sharers. If this is correct the statistical odds of being wrongly accused cannot be ignored.

You can download this report at: **www.beingthreatened.com/resources/The-Speculative-Invoicing-Handbook.pdf**.


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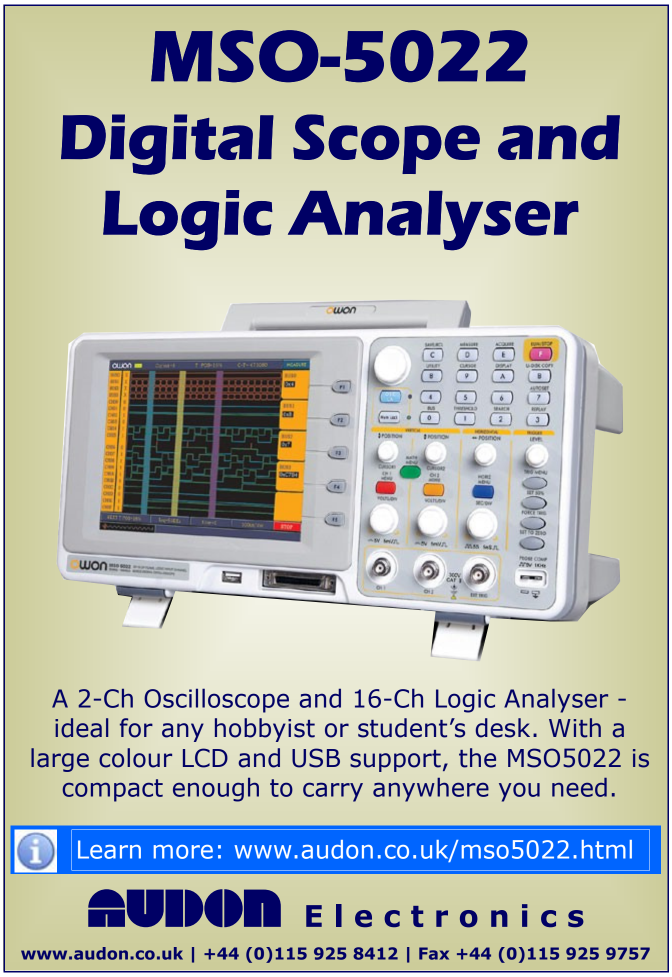
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PIC-Based Water Tank Level Meter

Part 1: By JOHN CLARKE

Optional radio telemetry feature lets you remotely monitor up to 10 tanks and automatically control pumps

Looking for a water tank level meter that's easy to install? One that's accurate, but doesn't need a complicated in-tank sensor? This PIC-based unit uses a pressure sensor to monitor water level and it displays tank level at the press of a switch. It can also send its readings to a base station with an LCD readout via an RF link.

SAVING WATER is vital, the 'green lobby' is continually advising us, and using rainwater tanks to store otherwise wasted precious rainwater is now all the rage. Why pay for water when you can catch it for free!

One traditional problem with water tanks is checking how much water is in them. That's because they are opaque and they are made that way to protect the water from sunlight which would otherwise promote algae growth.

Trying to look down through the water inlet into the dark interior doesn't help much because this is invariably gauzed over to keep insects out. And although some large concrete tanks have a manhole, this usually takes some effort to remove, so it's not a convenient way to check the water level.

Add-on devices

Many ingenious devices have been developed over the years to show the

water level in tanks. These include simple passive indicators that use clear tubing as a sight glass, mechanical floats and pulleys that move up and down with the water level, and the more complex electronic gauges.

Each has its advantages and disadvantages. For example, sight 'glass' systems, although simple, eventually become impossible to read because of algae growth and discolouration of the transparent material due to minerals in the water. And if the tube is directly exposed to the sun, it tends to become brittle.

Similarly, mechanical float and pulley systems require regular maintenance, otherwise they become jammed. In addition, none of these mechanical gauges easily provide for remote monitoring.

Electronic gauges are more complex, require power and are usually more costly. However, they can provide features that passive and mechanical gauges cannot. These features include reliability, accuracy and the ability to provide remote monitoring of one or more tanks at a time. In addition, provision is often made to include pump control.

This new Water Tank Level Meter includes all those features and more.

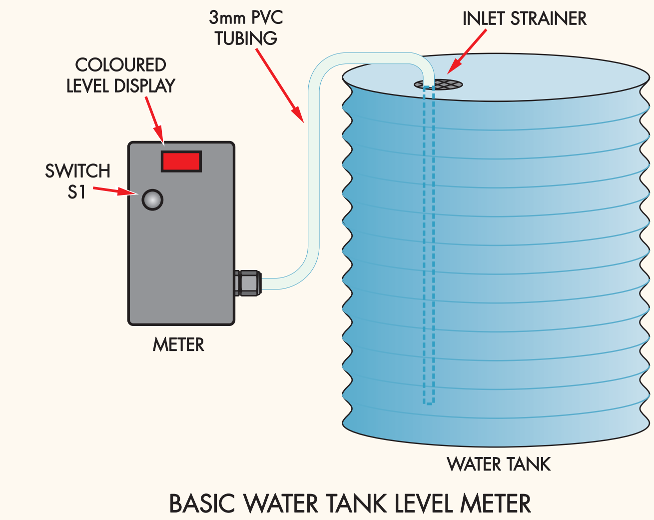


Fig.1: in its most basic form, the Water Tank Level Meter is a standalone unit that sits next to the tank. The water level is sensed using a pressure sensor connected by a plastic tube.

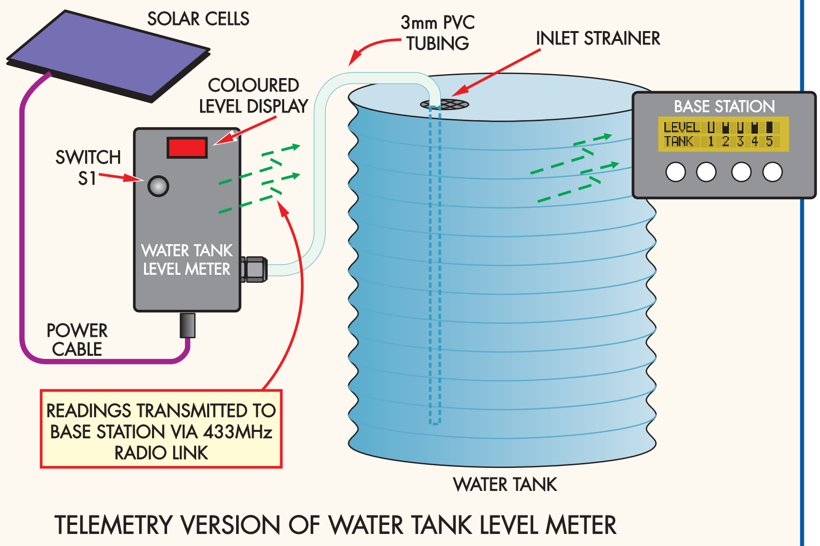


Fig.2: the telemetry version transmits its reading to a remote Base Station, which can display a range of data. A solar cell panel recharges an internal NiMH or NiCad battery.

Basic concept

The Water Tank Level Meter is a versatile unit that can be built in a number of different configurations. It suits all types of rainwater tanks, is easy to install and because it doesn't rely on mains power, can be installed just about anywhere.

That last feature is particularly important because mains power is often not available adjacent to water tanks and this makes many electronic tank level meters impractical.

By contrast, this Water Tank Level Meter is powered from a single AA alkaline or rechargeable cell, making it independent of the mains. It doesn't matter whether your tank is attached to the house, sat next to a shed away from the house or situated half way up a hill to provide water pressure storage – this unit will still work.

In its most basic form, this water level meter can be built as a standalone unit that's installed adjacent to a tank. The basic arrangement is shown in Fig.1.

All you have to do is press a push-button switch and a multi-coloured LED will display the water level. Water levels are displayed as a colour sequence, ranging over 10 colours from white through to violet, to violet/indigo, indigo, indigo/blue, blue, green, yellow, orange and red. Red indicates the lower 10% range followed by orange for the 10% to 20% range and so on up to violet for an 80% to 90% level and white for the 90% to 100% level – see Fig.3.

A single AA alkaline cell provides power for this basic version of the Water Tank Level Meter. The circuit draws no power until the pushbutton switch is pressed to activate the LED display. Actual cell life depends on usage, but with one water level check per day, the cell should last for around four years.

If you want higher water level resolution and remote monitoring, the unit can be upgraded to a telemetry unit. In this case, the tank level is transmitted to a separate (plugpack-powered) base station – see Fig.2. Note, however, that the tank level can still be checked using the LED display.

Base station

The base station shows levels in 1% increments from 0% through to above 100%. Why show levels above 100%? Well, most tanks are full when the water level reaches either the overflow

Main Features

Basic version

- Powered by a single cell
- Zero power consumption unless displaying the level
- Water level displayed using a 10-colour LED indicator
- Pushbutton initiates the display
- Easy installation using a length of plastic tubing into tank
- Weatherproof housing

Telemetry version

- Powered by an Alkaline, NiMH or NiCad cell
- Solar cell charging for rechargeable cell
- Pushbutton initiates the 10-colour level display
- Minimal power drawn from cell
- Radio transmission of tank level, temperature and cell voltage
- Up to 10 tanks can be monitored at the base station by using 10 water level meters
- Automatic pump control facility (requires Base Station and separate Pump Control unit)
- 16 encoding selections (prevents interference from a neighbour's Water Tank Level Meters)
- Four transmission update selections
- Update period differs slightly between each tank monitor to minimise data send clashes
- Easy installation using a length of tubing into the tank for height measurement
- Accurate measurement of regularly shaped tanks, including tanks with corrugated sides
- Weatherproof IP65 housing (protected from ingress of dust and water)

outlet or the bottom of the inlet strainer when there is no overflow outlet. This is the 100% full level.

However, during periods of heavy rain or when the tank is being filled using a pump, the tank can overfill. It is this condition that can be monitored via the base station readout – ie, to the '110% level'.

Up to 10 tanks can be remotely monitored using the base station. To do this, each Water Tank Level Meter (one for each tank) uses an inbuilt radio transmitter to send the data to the base station. This transmitter operates on the licence-free 433MHz band.

The distance over which the data can be sent depends on the terrain. Our tests indicate a range of more than 250m in open country, but this is reduced if the signal has to pass through a wall or roof to reach the base station, especially if there is corrugated iron in the transmission path.

The data is sent to the base station once every 16.8s, 33.5s, 67s or 268s (about 4½ minutes), depending on the set-up. This rate is selectable and depends on your installation.

For small tanks, you may want to choose a fast rate so that the reading updates can keep pace with the water level as the tank rapidly fills. The downside of a fast rate is that the circuit draws more power from the cell. So while an alkaline cell could be used to power each Water Tank Level Meter, the best power option for the telemetry version is to use a rechargeable cell, along with a solar cell to recharge it.

The slowest rate (ie, 268s) can be used to conserve power and is more suited for large tanks. It's also an acceptable update period for most other installations, where you just want to know the water level and don't have pump control.

Pump control

The base station not only shows water levels, but can also independently control up to 10 electric water pumps. For example, the base station can be set up to switch off a given pump when the tank water drops below a preset level. This is useful when pumping out of a tank.

Alternatively, a pump can be switched off if the water rises above a preset level; eg, when filling a tank. A pump can also be switched off if the temperature drops below a preset value, to prevent the pump from running when the water is frozen.

In addition, the pump control includes brownout protection. We'll have more to say about this and pump control in a later article.

Water Tank Level Meter

Now that we've covered the basic features, let's go back and take a closer look at the Water Tank Level Meter.

Basically, you require one of these meters for each tank. As shown in the photos, the unit mounts in a weatherproof box with a clear lid to allow the coloured LED to be seen (for water level indication). The front panel carries a waterproof switch, while the plastic tube that is required for tank level measurement enters the box via a waterproof cable gland.

Unlike the basic version, the telemetry version uses a rechargeable cell, and this is recharged by a separate solar cell panel during daylight hours. The leads from the solar panel enter through a waterproof cable gland on the bottom of the box.

Measurement techniques

Just about every water tank level meter on the market measures water height within the tank. They do not measure water volume because that is difficult to do and is usually unnecessary.

If the tank is a regular shape with nominally straight sides and with the same shape and area at any horizontal cross section, then the water level gives a direct indication of water volume. By contrast, irregularly-shaped tanks, such as those that have large

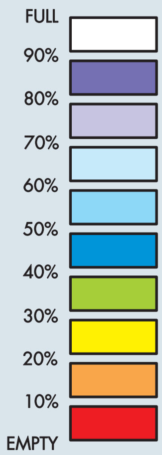


Fig.3: the water level in the basic version is displayed using a 10-colour sequence, ranging from red (0-10%) to white (90-100%). These colours are generated by a tri-colour LED.

indentations or are moulded to fit into an available space are not suited to accurate level measurement.

Tanks that taper slightly (in the vertical direction) due to the use of thicker material towards the base do not alter the accuracy markedly. Similarly, corrugations have only a small effect on accuracy, although this gets worse at very low water levels and where the tank diameter is small compared to the corrugation depth. In general though, the small non-linearity of volume with height does not matter.

Water levels

There are several electronic techniques that are used to measure water level in a tank. One method is to use an in-tank sensor with a series of vertically-spaced metal contacts. As the water rises, current flows through each successive contact (because water is a good conductor) and the associated electronic circuit displays the level.

The resolution of this type of meter depends on the number of vertical contacts. This type of water level meter was described in the March '09 issue of *EPE* (five levels and 10 levels respectively).

Another method involves using an ultrasonic sensor to measure the distance from the top of the tank to the surface of the water. However, ultrasonic transducers require more power than we care to draw from an AA cell and the measurement is unreliable while the tank is filling.

Why is it unreliable? Well, as the water enters the tank inlet, the droplets scatter the ultrasonic signal and the measurement is lost.

Pressure sensor

Unlike our previous designs, the Water Tank Level Meter described here uses a pressure sensor to measure water height. This is a very simple method that provides excellent accuracy and is easy to install – all you have to do is connect the free end of a hose to the pressure sensor and feed the other end of the hose into a tank.

The technique relies on the fact that water pressure increases with increasing depth. For water, the pressure increases by 9.8kPa per metre, and so there is approximately an extra atmosphere (1013hPa or 101.3kPa) of pressure for every 10.3m of depth.

Refer now to Fig.4. As shown in Fig.4a, if the free end of the hose is left open, the hose will fill to the same level as the water in the tank.

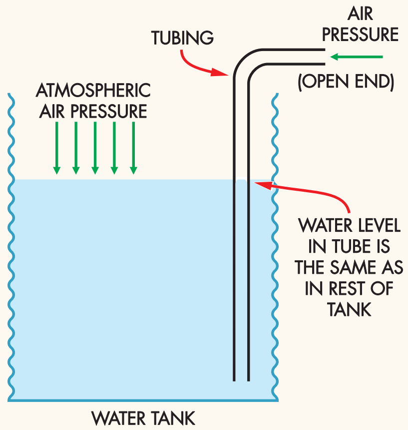
However, if we first connect the free end to a pressure sensor, and then place the hose in the tank, the water will still rise inside the tube, but not to the water tank level (see Fig.4b). That's because it pressurises the air trapped inside the tube. In fact, the water level within the tube stabilises when the pressure inside the tube equals the water pressure at the bottom of the tube.

Fig.4c shows what happens if the water level drops below the bottom of the tube. In this case, the reading will be zero, since both inlet ports on the sensor are at atmospheric pressure (ie, the unit is calibrated to measure zero pressure when there is no water in the tank, with the pressure then progressively rising as the water level rises).

One problem with this scheme is that the tube will not stay down of its own accord, but will float due to the air trapped inside it. Fortunately, that's easy to overcome by tying it to a length of PVC pipe. Alternatively, it can be 'tied' down using a weight.

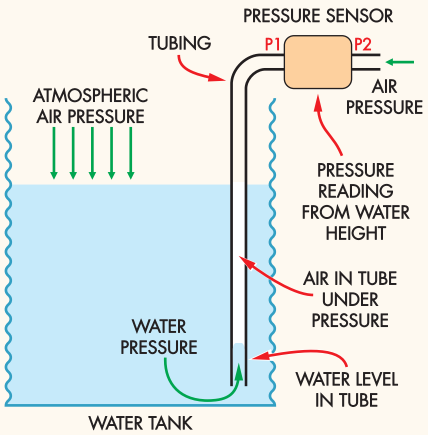
Temperature variations

Another problem concerns the effect of temperature variations on the air pressure inside the tube. For example, if the sun heats the tube, the air inside it will expand and displace some of the water out of the tube.



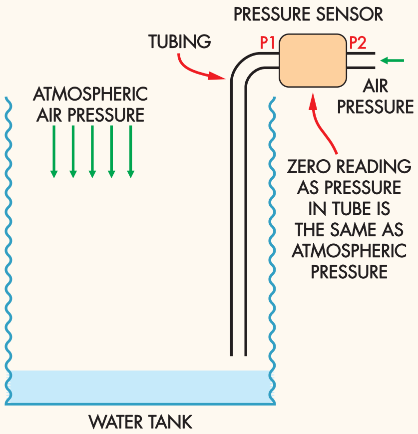
A TUBING WITH OPEN END

Fig.4a: if the free end of the tube (or hose) is left open, the tube fills to the same level as the tank.



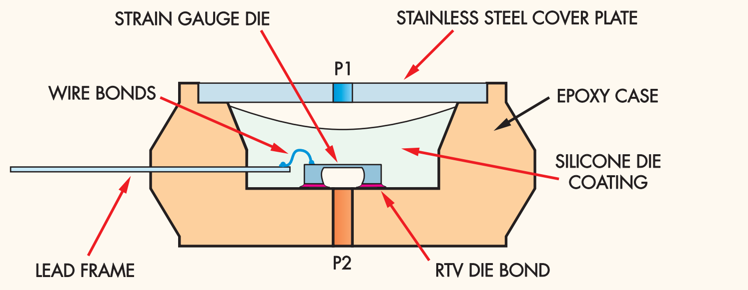
B WITH PRESSURE SENSOR, END OF TUBE NEAR TANK BOTTOM

Fig.4b: if one end of the tube is connected to a pressure sensor, the water pressurises the air in the tube.



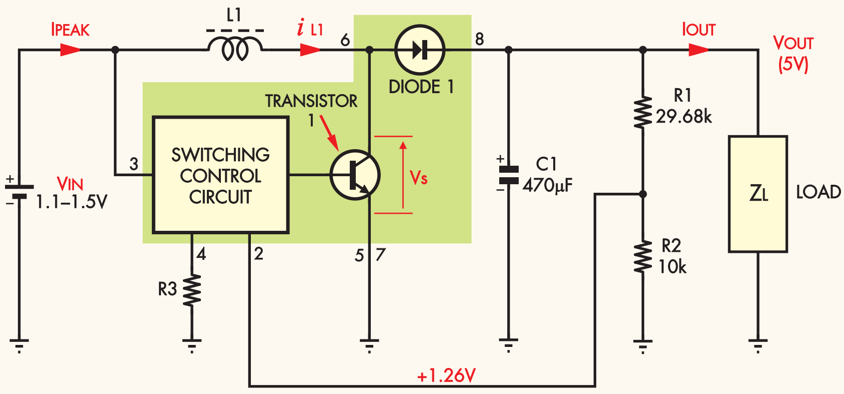
C WITH PRESSURE SENSOR, TUBE END AT SURFACE

Fig.4c: if the water level drops below the bottom of the tube, the reading will be zero since both sensor ports are at atmospheric pressure.



INSIDE THE PRESSURE SENSOR

Fig.5: this cross-section diagram shows the internal structure of the MPX-2010DP pressure sensor. The strain gauge varies its resistance according to the applied load. Note that there are two port openings (P1 and P2).



TL499A STEP UP CIRCUIT

Fig.6: the basic circuit for the step-up switching regulator. Transistor Q1 is repeatedly switched on and off by the control circuit. When it is on, the current builds up through L1 and when it switches off, the energy stored in L1 is transferred to the load.

In practice, this pressure variation is compensated for by measuring the temperature and modifying the measurement accordingly. We can also minimise this pressure variation by making sure the length of tubing outside the tank is short compared to the overall length and by keeping the exposed part out of the sun.

Another problem that must be taken care of is the effect of atmospheric pressure variations. As shown in Fig.4, the atmosphere presses down onto the water and so the water level readings could vary markedly as the atmospheric air pressure changes.

The solution to this problem is simply to use a differential pressure sensor. This type of sensor is vented to the atmosphere, and so this variation is removed from the measurement.

Pressure sensor

In order to explain how the sensor ignores the atmospheric air pressure, let's take a look at its internal construction – see Fig.5.

The sensor used here is the MPX-2010DP from Freescale Semiconductor. Note that 'RTV die bond' stands for 'Room Temperature Vulcanising' bonding. In other words, silicone glue is used to bond the strain gauge die to the epoxy casing and it is cured at room temperature.

Inside the sensor is a strain gauge that varies its resistance according to the applied load – ie, the air pressure exerted on the gauge. Note that there are two port openings to the strain gauge. One is on the top side and is designated port 1 (P1), while the other is on the lower side and is designated port 2 (P2).

If the same pressure is applied to both P1 and P2 then the strain gauge does not flex. However, if one port has more pressure than the other, then the strain gauge bends and its resistance changes.

This particular sensor is called a differential type because it measures the difference in pressure between the two ports – ie, its output only changes when the pressure difference between the two ports changes.

The MPX2010DP is designed for the pressure at port 1 to be greater than or equal to the pressure at port 2. In addition, port 1 has a silicone gel protective layer to prevent moisture affecting the strain gauge element. This makes the sensor ideal for water level measurement, as the silicone barrier keeps the sensor free of the water vapour that results from condensation in the measuring tube.

By contrast, Port 2 is vented to the atmosphere, to balance the air pressure on both sides of the strain gauge element.

This sensor is specified for a 0-10kPa pressure range, with a maximum differential pressure of 75kPa. Using it above the 10kPa level degrades the linearity due to internal self-heating of the sensor. However, this limit is specified when running the sensor from a 10V supply. Since we are using a 5V supply, the self-heating will be considerably lower and so we can easily exert more pressure than 10kPa without loss of linearity.

When connected to measure water level, each metre of water adds 9.8kPa of pressure to the sensor. Most water tanks are equal to or less than about 2.2m in height because they are designed to fill from the rainwater guttering of a house. This means that, for a 2.2m tank, the maximum pressure applied to the sensor will be about 22kPa maximum. This is well below the 75kPa maximum allowable for the sensor.

The strain gauge element is temperature compensated within the sensor by connecting it in a balanced bridge arrangement and by laser trimming the elements during manufacture. In practice, the sensor is compensated over a 0 to 85°C range, but can be operated from –40°C to +125°C.

Circuit details

As stated previously, the unit is powered from a single cell – either a 1.5V rail from a standard alkaline cell or a 1.25V rail from an NiMH (or NiCad) rechargeable cell. This voltage needs to be stepped up to 5V to run the microcontroller (IC1) and its associated circuitry – see Fig.6.

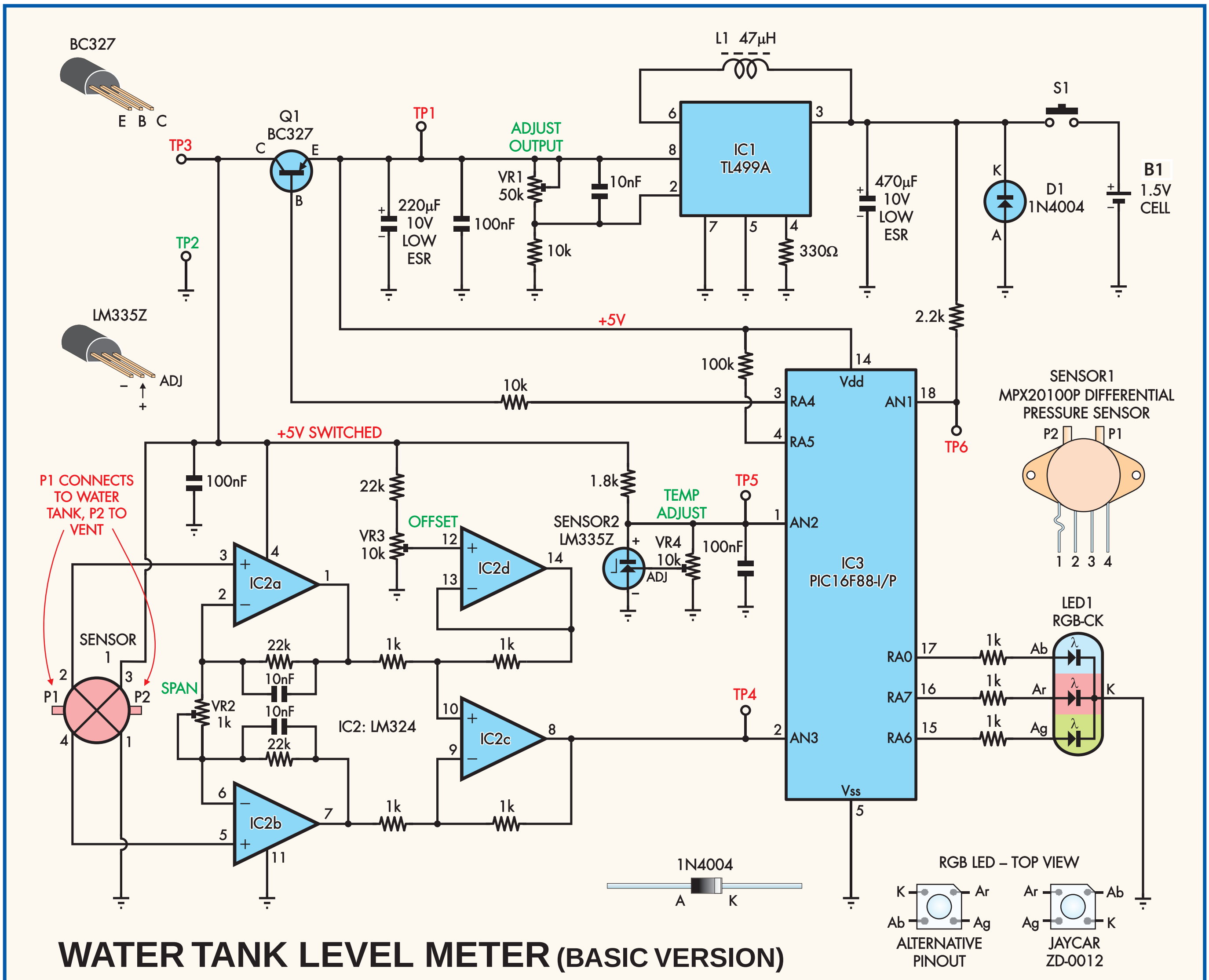


Fig.7: this is the circuit for the basic version of the Water Tank Level Meter. The differential outputs from the pressure sensor at pins 2 and 4 are buffered and amplified by op amps IC2a-IC2d and then fed to inputs AN2 and AN3 (pins 1 and 2) of a PIC18F88-I/P microcontroller (IC3). IC3 processes the data and drives a tri-colour LED at RA0, RA6 and RA7.

This voltage step-up is performed using a TL499A switching regulator (IC1), transistor Q1, inductor L1, a series diode (D1) and output filter capacitor C1.

The circuit works like this: initially, transistor Q1 is switched on and the current through inductor L1 builds up until it reaches a preset value, as set by the resistor connected to pin 4 of IC1. At that point, the transistor switches off and the energy stored in L1 is delivered to the load and to output capacitor C1 via the series diode D1. This process then repeats, with the transistor switching on again and recharging L1, then switching off again and transferring the charge in L1 to the load (ZL).

A voltage divider consisting of resistors R1 and R2 reduces the output level, while Q1's switching is controlled so as to maintain 1.26V at pin 2. Basically, the voltage divider values of 29.68k and 10k divide the output by 3.97, so the output will be at 5V when there is 1.26V at pin 2.

Should the voltage rise slightly above 5V, transistor Q1 stops switching until the voltage falls slightly below the 5V level. Conversely, if the output voltage falls below 5V, the transistor switches on and off at a fast rate to increase the voltage.

Note that the 1.26V at pin 2 (necessary to maintain regulation) is only a nominal value and could in fact be anywhere between 1.2V to 1.32V, depending on the particular IC used. As a result, resistor R1 needs to be adjustable so that the output voltage can be set precisely to +5V.

Basic circuit

Refer now to Fig.7 for the circuit details of the Water Tank Level Meter (Basic Version).

As shown, power from the 1.5V cell (B1) is applied to pin 3 of step-up converter IC1 via switch S1. Diode D1 provides reverse polarity protection if the cell is inserted incorrectly, while a 470μF low-ESR capacitor bypasses the supply. This capacitor provides the necessary transient current for the inductor (L1) when transistor Q1 switches on.

The Base Station goes with the Telemetry Version of the level meter and can display a range of data, including individual levels for up to 10 tanks and pump control set-up. It will be described next month.

If B1 is connected the wrong way around, D1 conducts heavily and limits the reverse voltage at pin 3 and across the 470µF capacitor to less than 1V. In addition, many single cell holders are designed to prevent the cell from making contact with the positive contact if it is inserted incorrectly.

Power is drawn from the 1.5V cell only when switch S1 is pressed. This means that the cell should last for several years before it requires changing, depending on the amount of use. The current consumption from the cell when the switch is pressed with one or two LEDs alight is typically around 32mA.

IC1's output voltage appears at pin 8 and is sampled via trimpot VR1 and a 10kΩ resistor. This sampled voltage is then applied to pin 2.

In practice, VR1 is adjusted so that the output is exactly +5V. A 100nF ceramic capacitor and a low-ESR 220µF capacitor filter this supply rail, which is then fed to pin 14 of microcontroller IC3. The +5V rail is also connected to the emitter (E) of transistor Q1 (BC327).

When power is applied to IC3, its internal software program starts running. Initially, transistor Q1 is switched off because IC3's RA4 output (which drives Q1's base via a 1kΩ resistor) is held at +5V. As a result, no power is applied to either the pressure sensor (Sensor1) or IC2. However, after a short period to allow the +5V rail to stabilise, RA4 goes low and Q1 switches on. Sensor1 and IC2 are then powered up and begin operating.

Differential outputs

As shown in Fig.7, Sensor1 has differential outputs at pins 2 and 4. If the same pressure is applied to both ports, the voltages at pins 2 and 4 are nominally the same, at half supply voltage or 2.5V. However, if the pressure at port 1 is higher that at port 2, the voltage at pin 2 rises and the voltage at pin 4 falls. This change in voltage is actually quite small, amounting to around 12.5mV for a 10kPa pressure difference when the sensor is powered from a 5V rail.

The sensor's differential output signals at pins 2 and 4 are fed to op amps IC2a and IC2b respectively. These are each set up as non-inverting amplifiers with 22kΩ feedback resistors and with a 1kΩ trimpot (VR2) connected between their inverting inputs. The 10nF capacitors across the 22kΩ resistors, filter the signal by rolling off the high-frequency response.

The outputs from IC2a and IC2b appear at pins 1 and 7 respectively, and are summed in unity gain differential amplifier IC2c. Basically, IC2c acts as a voltage follower for the positive-going signals from IC2a and as an inverter for the negative-going signals from IC2b. As a result, the signal voltage excursions from IC2a and IC2b are effectively added together. The overall gain is 1 + (22kΩ x 2/VR2).

Buffer stage

Op amp IC2d is wired as a buffer stage and applies an offset voltage to the non-inverting input of IC2c (pin 10) via a 1kΩ resistor. It obtains its reference voltage via a voltage divider from the +5V supply and this divider comprises trimpot VR3 and a 22kΩ resistor.

In practice, VR3 is adjusted so that IC2c's pin 14 output sits at 1V when the sensor has no pressure difference between the two inlet ports. By contrast, trimpot VR2 is adjusted to provide 3V at IC2c's pin 8 output when the sensor is measuring a full tank.

As a result, IC2c has a 2V range – ie, from 1V to 3V for a zero to full tank level measurement.

If the tank being monitored is 1m high, the sensor output will provide

a 12.5mV signal when the tank is full. In this case, the signal must be amplified by 160 to produce the required 2V swing and that means that VR2 would be set to 277Ω.

Trimpot VR2's practical range from 1kΩ down to about 100Ω easily provides for tanks ranging in height from 3m down to 360mm. However, in the unlikely event that a tank is less than 360mm high, a 200Ω trimpot should be used for VR2 instead of the 1kΩ value specified on the circuit. This will allow the trimpot to be set below 100Ω without being too near its adjustment limit.

The reason we restrict IC2c's output to between 1V to 3V is so that the LM324 op amp (IC2) can operate correctly within its output range. Typically, an LM324 can easily provide an output from 1V to 3V when powered from a 5V rail, but it cannot provide a 0V to 5V output.

Specifications

Water Level Indication: white 90-100%, violet 80-90%, violet/indigo 70-80%, indigo 60-70%, indigo/blue 50-60%, blue 40-50%, green 30-40%, yellow 20-30%, orange 10-20%, red 0-10%

Current – Basic Unit: 32mA typical when displaying level; 0mA when off

Current – Telemetry Version: standby current drawn from 1.25V cell = 1mA; awake current during each start-up for 220ms = 24mA; average current = 314µA for 16.8s update; 157µA for 33.5s update; 79µA for 67s update; and 19µA for 268s update. Add an extra 8mA over 2s when one or two LEDs are lit

Solar cell charge current in winter time and in full sunlight: typically 30mA

Data transmission duration: 146ms

Transmission repeat: approximately 16.8s for encode 0-3, 33.5s for encode set at 4-7, 67 seconds for encode set at 8-B and 268s for C-F.

Transmit range: over 250m

Microcontroller

IC2c's output at pin 8 is applied to the AN3 input (pin 2) of IC3, a PIC16F88-I/P microcontroller. Note, however, that the 5V supply is applied to Sensor1 and to IC2 for about 64ms before the voltage at AN3 is measured. In operation, IC3 converts this applied voltage to a 10-bit digital value and this is then calculated as a percentage, with a 1V reading converted to 0% and a 3V reading converted to 100%. The 100% to 110% range covers input voltages between 3V and 3.2V.

The resulting percentage level is then used to determine what colour should be produced by the tri-colour (RGB) LED. This device basically includes separate red, green and blue LEDs, and these are driven by the RA0, RA7 and RA6 outputs via 1kΩ resistors.

When all the LEDs in the package are powered, the LED colours mix to show white. If only two or one LED is lit, a different colour results. For example, to produce violet, the red and blue LEDs are lit. Similarly, yellow is displayed when the red and green LEDs are lit.

We can also obtain a range of in-between colours by reducing the light output of one of the LEDs. This is achieved by switching the LED on and off using a fast equal duty cycle waveform, so that it doesn't appear to flicker. For example, to obtain orange, we switch the red LED on continuously while the green LED is rapidly switched on and off.

In practice, when switch S1 is momentarily pressed, the LED colour display comes on for about two seconds to show the water level and then switches off again. At the same time, IC3's RA4 output goes high and switches off transistor Q1 to disconnect power to the pressure sensor and IC2. This conserves power should the switch be pressed longer than required.

The 2.2kΩ resistor at pin 18 (AN1) of IC3 ties this input to pin 3 of IC1 so that it is not left floating (this input is used in the telemetry version to measure cell voltage).

Temperature sensing

The AN2 input (pin 1) monitors the temperature via an LM335Z temperature sensor (Sensor2). This produces a nominal output of 10mV/°C, but with an offset of 2.73V at 0°C and is linear with temperature changes. The water level reading is then compensated for according to the measured temperature.

Trimpot VR4 is used to calibrate the sensor for 2.73V at 0°C or 2.98V at 25°C by altering the voltage at the ADJ terminal.

Clock signals for IC3 are provided by an internal oscillator that's set to run at 8MHz. Among other things, it runs the internal program at a constant rate to perform the A/D conversion and to drive the RGB LED for the set period.

Telemetry link

The telemetry version of the Water Tank Level Meter is almost the same as the standard version, but adds a few extra parts, including a 433MHz transmitter and two rotary BCD switches. In addition, the power supply arrangement is slightly different – see Fig.8.

As previously mentioned, this version is powered from a rechargeable NiMH (or NiCad) cell. This cell is in turn charged from a solar cell array via Schottky diode D2. This diode is required to stop the solar cell from discharging the NiMH cell when there is no sunlight.

In case you are wondering, you could still use an alkaline cell to power the unit and do away with the solar cell charger. However, the cell would require changing every two months.

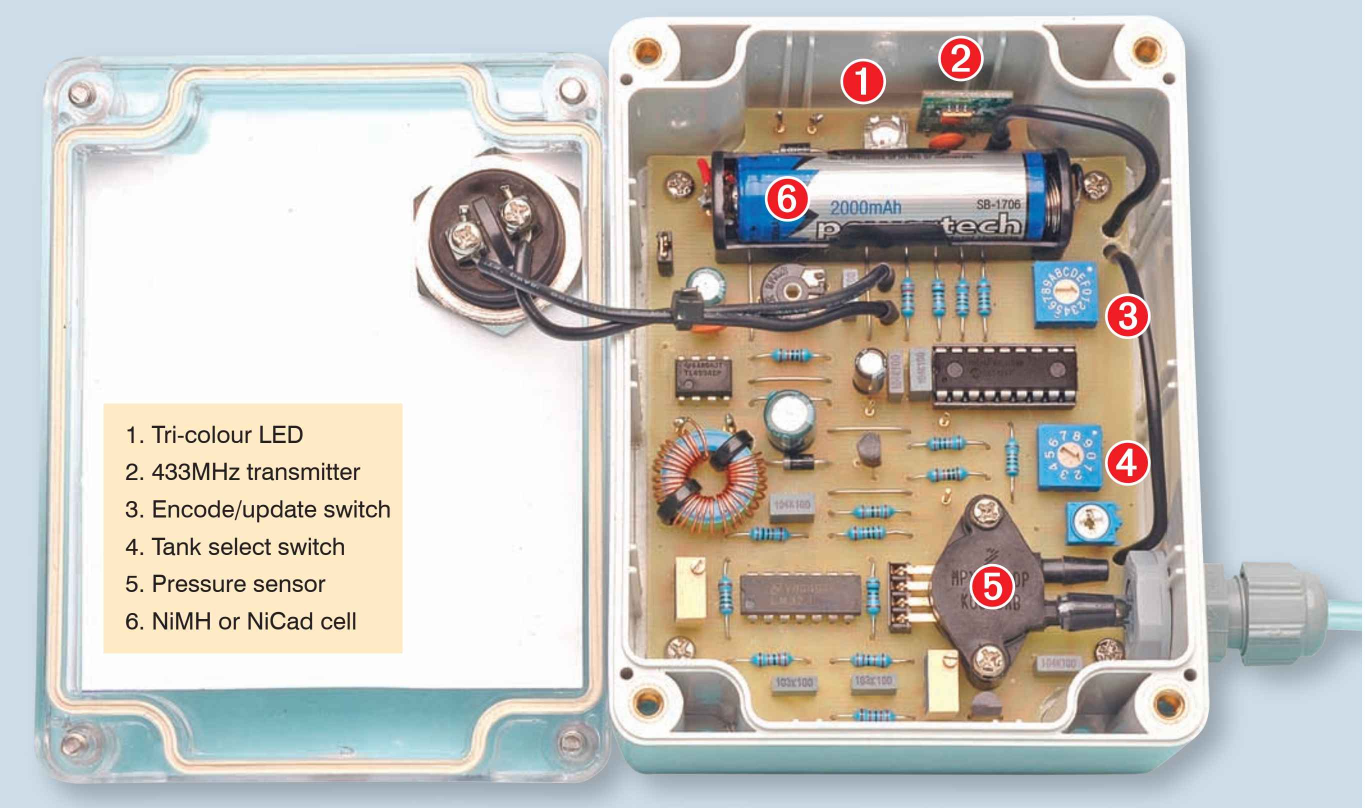
Another alternative is to run the circuit from a mains plugpack. In this case, an NiMH (or NiCad) cell must be used, and this is recharged from the plugpack. In addition, diode D2 must be replaced with a 1kΩ 0.25W resistor.

Other supply changes to the circuit include moving S1 so that it now connects across transistor Q1. Switch S1's previous position is now replaced by link LK1, which means that power is now continuously applied to step-up converter IC1, which in turn permanently powers the microcontroller (IC3).

Saving power

To conserve power, IC3 is normally in a sleep mode; ie, its internal oscillator is stopped, its A/D converter is off and the program is halted. In this mode, IC3 typically draws just 11µA.

During this period, a watchdog timer is left running (more about this timer soon) and the RA4 output is set high so that transistor Q1 is off. As a result,



Here's a preview inside the Water Tank Level Meter. This unit has the extra parts required for the Telemetry Version (ie, the BCD switches and the 433MHz transmitter module). The pressure sensor is at bottom right, although the author now recommends that it be mounted off the PC board (see Part 2 next month).

there is normally no supply to Sensor1, IC2, the 433MHz transmitter module and all those other components that derive their supply from the +5V switched rail.

We have also minimised the current drain due to BCD switches BCD1 and BCD2. These switches can connect any of their '1', '2', '4' or '8' inputs to the common pin (C), depending on the switch setting.

These inputs are usually tied to +5V via internal pull-up resistors (typically 20kΩ) at the RB0-RB2 inputs for BCD1 and the RB3-RB6 inputs for BCD2. The RA5 input for BCD1 is pulled to +5V using an external 100kΩ resistor. The 1kΩ resistor between BCD1 and RA5 is necessary because this input is susceptible to currents that flow into or out of the pin when voltages go above or below the supply (these currents can reset IC3).

Normally, if IC3 is to determine which settings are selected for the BCD switches, their common (C) connections must be at ground level so any closed switch will pull the normally high input to ground. However, this would cause extra current flow because the corresponding pull-up resistors would be connected across the 5V supply and thus be drawing up to 250µA extra current for each closed switch.

To prevent this current, we have connected the common pins to the RA4 output of IC3 instead. This output is high at +5V when the microcontroller is in sleep mode, and so whether a switch is closed or not, the BCD switches will not add to power consumption. The RA4 output subsequently goes low when IC3 is awake to allow the switches to be read.

This also means that the switch-mode step-up circuit comprising IC1 and its associated components does not need to supply much current to IC3 when it is in sleep mode. As a result, IC1 charges L1 for just 28µs once every 6ms and this is just enough to maintain the 5V supply. By contrast, when the supply is required to deliver current to the whole circuit, L1 is charged for 28µs every 150µs.

Reawakening

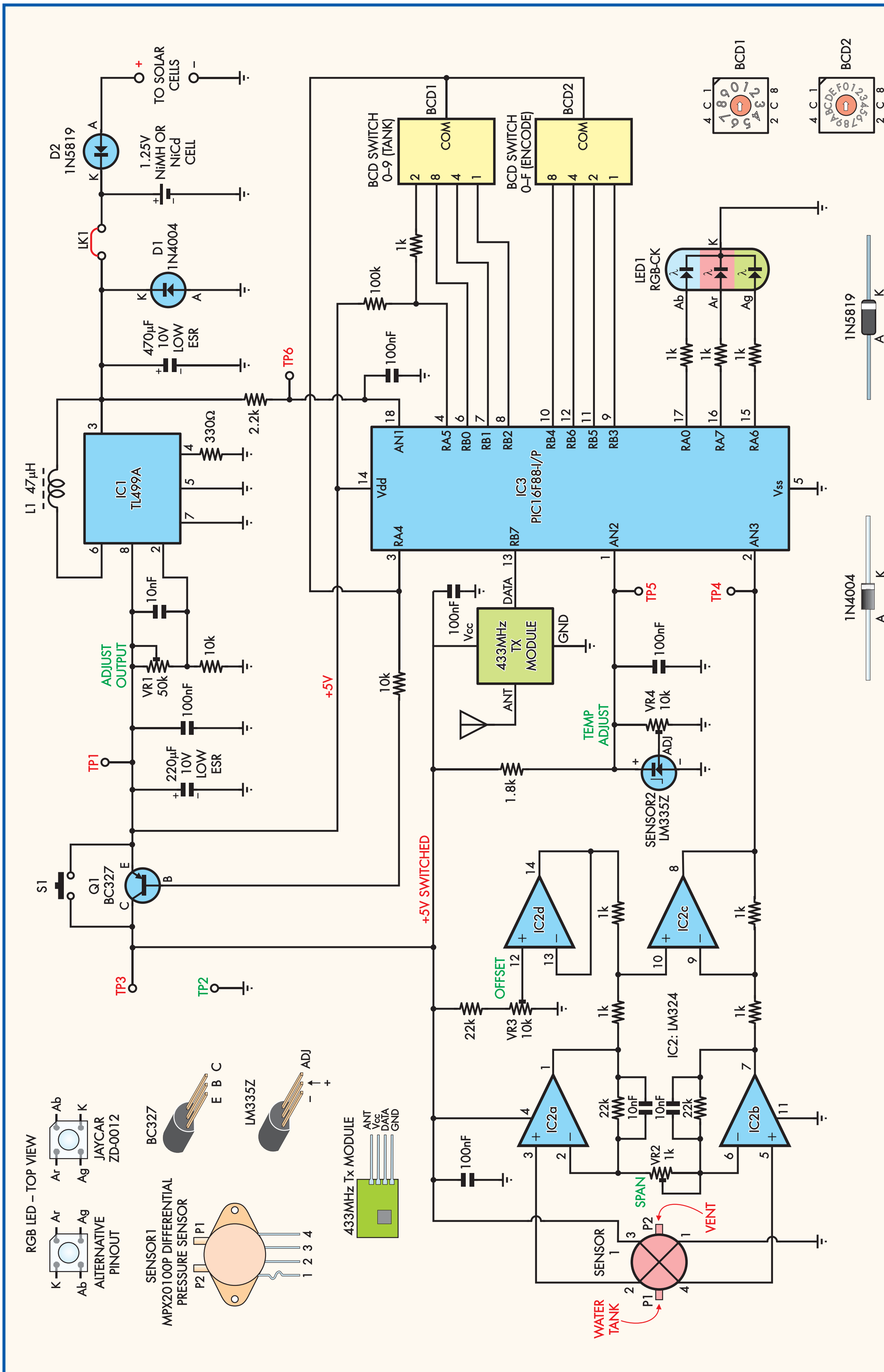
IC3 will 'wake up' on any one of two events. The main event is when the watchdog timer times out and wakes IC3 from its sleep. In this case, the oscillator starts up and the internal program starts running.

Basically, the watchdog timer will timeout every 16.8s, 33.5s, 67s or 268s, depending on the switch selection for BCD2. The period between 'wake-ups' is the update period – each time IC3 wakes up, the water tank level is measured and the data transmitted to the base station. After sending this data, the microcontroller then returns to its sleep mode to conserve power.

Note that a watchdog wake-up does not light the tri-colour RGB LED, and this is again done to conserve power.

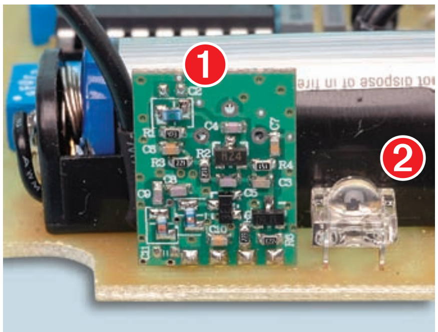
In order to light the RGB LED for a tank level display, switch S1 (now in parallel with Q1) must be pressed. In addition, IC3 needs to be woken from its sleep independently from the watchdog timer through a different process.

Note that during the sleep mode, the AN1 (pin 18) and AN2 (pin1) inputs of IC3 are set to connect to a comparator within IC3. The AN1 input is at the cell voltage (1.2V), while the AN2 input is at 0V because transistor Q1 is off. As a



WATER TANK LEVEL METER (TELEMETRY VERSION)

Fig.8: the Telemetry Version is similar to the Basic Version, but adds in a couple of BCD switches and a 433MHz data transmitter module. The BCD switches allow tank selection and set the data update periods.



This larger than life-size view shows the 433MHz transmitter module (1) and the tri-colour LED (2) mounted at one end of the PC board. The LED colour indicates the water level.

result, the output of the internal comparator is low because the pin 18 inverting input of the comparator is higher than the pin 1 non-inverting input.

That leads us to the second way of waking up IC3 – by manually pressing switch S1 and forcing the comparator output to go high. It works as follows.

When S1 is pressed, it bypasses Q1 and supplies power to the temperature sensor (Sensor2) via a 1.8kΩ resistor. With power applied, Sensor2 will now have at least 2.5V across it and the comparator's pin 1 input (AN2) will now be greater than the 1.2V from the cell.

As a result, the comparator output goes high and this wakes up IC3. And when that happens, the processor maintains power to the sensors and the 433MHz transmitter by bringing its RA4 output low to turn on Q1.

Regardless of how it wakes up (ie, either via the watchdog timer or by pressing S1), IC3 measures the temperature, cell voltage and tank level. It then transmits this data via a 433MHz transmitter module that is connected to pin 13 (RB7). At the same time, the tri-colour LED also lights for about 2s to show the tank level.

Note that before measuring the temperature and cell voltages, IC3 changes its AN1 and AN2 ports to digital inputs. This allows IC3 to measure the cell voltage at pin 18 via a 2.2kΩ resistor and 100nF filter capacitor, and to monitor the temperature at pin 1.

As with the basic version, the temperature is monitored using an LM335Z temperature sensor. This part of the circuit works as before.

At the AN2 input, the temperature sensor voltage is converted to a 10-bit digital value. This is then converted to °C by the software and the digital data transmitted to the base station, where it is displayed on the LCD panel. The temperature which can be displayed ranges from –99°C to 100°C.

Note that the temperature reading can be used to switch off a pump if the temperature drops below a preset point. This is done via the base station and a separate pump control circuit – to be described.

Cell voltage

The cell voltage is measured at the AN1 input. This input converts the voltage to a 10-bit digital value, which is again transmitted to the Base Station for display.

The displayed voltage is a good indicator of battery charge. A cell voltage that is 1.15V or less has a small 'x' located at the top left corner before the '1' in the display reading, to indicate a possible problem with the cell.

Typically, a fully-charged NiMH cell will show more that 1.25V on the Base Station display.

BCD switches

Switch BCD1 is designated the 'Tank' switch. This switch can be set to any number from 1 to 9 or to 0, the number selected representing the tank number.

This means that if you have two Water Tank Level Meters (to monitor two tanks), you would set one as Tank 1 and the other as Tank 2. That way, the base station knows which tank is which.

The base station has a display option that shows all the selected tanks and their levels as a bargraph on the one display. The order of the display is 1, 2, 3..., up to 9 and then 0. The 0 tank is placed at the end because not too many people start counting tanks from 0!

The encode switch (BCD2) has two functions, one of which is to prevent any neighbouring tank level meters from sending data to your base station.

Thus, when a water tank level meter transmits its data to the base station, it also sends the encode selection. The Base Station must also have the same encode selection programmed into it to accept the data. This means that if a neighbour's tank levels are displayed on your base station (unlikely), then it is time to change the encode selection.

Note, however, that if you have several water tank level meters, these must all have the same setting for BCD2 and this must be identical to the Base Station encode switch.

The encode switch also alters the period between each data transmission of the tank level. If you have the encode switch set to 0, 1, 2 or 3, then the update period is 16.8s. Encode switch settings of 4 to 7 give a 33.5s update; settings between 8 and B give a 67s update; and settings from C to F give 268s, or about 4.5 minutes.

The selection you choose depends on the size of the tank to some extent, and the number of tanks being monitored. The fewer the tanks, the faster the update periods can be. A slower update rate avoids data clashes.

Minimising data clashes

Data clashes occur when one tank transmits its data during the same time period as another. This will cause incorrect data reception at the Base Station and the data will be rejected. The more tanks that are monitored the greater the likelihood of clashes. So we need to minimise these clashes or the data at the Base Station will not be updated very often.

Data clashes will be worse if each tank has exactly the same update period. For this reason, the tank selection switch BCD1 also alters the update rate slightly between selections. The change is not great and overall is of the order of ±12%, but that's enough to cause any data clashes between tanks to quickly drift apart. In addition, the encode selections at BCD2 also alter the watchdog timer oscillator by a small amount (this is in addition to the widely spaced update values of 16.7s, 33.5s, 67s and 268s).

As noted, clashes cause incorrect data to be received at the Base Station, so we need to ensure that the Base Station does not accept this incorrect data. As a result, several safeguards are included to ensure that only the correct data is processed and displayed.

First, we send a start locking code that locks the base station receiver to the transmitter frequency. As a result, data from another water tank meter will be at a different rate and so will not lock.

Second, the water tank level data and temperature data are sent twice and the base station checks if the

Parts List – Water Tank Level Meter

Basic unit
1 PC board, code 753, available from the *EPE PCB Service*, size,104 x 79mm
1 IP65 sealed polycarbonate enclosure with clear lid, 115 x 90 x 55mm (Jaycar HB-6246 or equivalent)
1 MPX2010DP Freescale Semiconductor 0-10kPa differential temperature-compensated pressure sensor (Jaycar ZD-1904 or equivalent) (Sensor1)
1 SPST waterproof momentary switch (Jaycar SP-0732 or equivalent) (S1)
1 18 x 8 x 6.5mm iron-powdered core (Jaycar LO-1242 or equivalent) (L1)
1 3-6.5mm diameter IP68 waterproof cable gland
1 AA cell – see text
1 AA cell holder
1 2-way pin header with 2.54mm spacing
1 18-pin DIL IC socket
1 4-way SIL socket (made from a cut down DIP8 socket)
2 M3 x 15mm screws
2 M3 nuts
2 No.4 x 6mm self-tapping screws
10 PC stakes
1 1.5m length of 0.5mm enamelled copper wire
1 150mm length of medium-duty hookup wire
1 270mm length of 0.8mm tinned copper wire
2 100mm cable ties
1 length of 3mm ID clear vinyl tube (length to suit water tank depth and installation)
1 length of 25mm PVC tubing to support the tubing or a suitable weight
4 200mm cable ties

Semiconductors
1 TL499A power supply controller (IC1)
1 LM324N quad op amp (IC2)
1 PIC16F88-I/P microcontroller programmed with 'water tank level meter.hex' (IC3)
1 LM335Z temperature sensor (Sensor2)
1 BC327 *PNP* transistor (Q1)
1 1N4004 1A diode (D1)
1 common cathode RGB LED (Jaycar ZD-0012 or equivalent) (LED1)

Capacitors
1 470µF 10V PC low-ESR electrolytic
1 220µF 10V PC low-ESR electrolytic
1 100µF 16V PC electrolytic
3 100nF MKT polyester
1 100nF ceramic
3 10nF MKT polyester

Resistors (0.25W 1%)
1 100kΩ	1 1.8kΩ
3 22kΩ	7 1kΩ
2 10kΩ	1 330Ω
1 2.2kΩ	

Trimpots
1 50kΩ horizontal trimpot (code 503) (VR1)
1 1kΩ multi-turn top adjust trimpot (code 102) (VR2)
1 10kΩ multi-turn top adjust trimpot (code 103) (VR3)
1 10kΩ horizontal trimpot (code 103) (VR4)

Extra parts for telemetry version
1 BCD 0-9 DIL rotary switch (BCD1) (Jaycar SR-1222 or equivalent)
1 BCD 0-F DIL rotary switch (BCD2) (Jaycar SR-1220 or equivalent)
1 433MHz transmitter module (Jaycar ZW-3100)
1 6.5mm diameter IP68 waterproof cable gland
3 PC stakes
1 2.54mm jumper shunt
1 Solar garden light – this includes the solar cell, an AA NiMH or NiCad cell and the 1N5819 Schottky diode (D2))
1 100nF MKT polyester capacitor
1 100nF ceramic capacitor
1 1kΩ 0.25W 1% resistor
1 length of single-core shielded microphone cable (length to suit installation)

Extra parts if pressure sensor mounted inside tank
1 bulkhead box, 65 x 38 x 17mm
1 4-way header with 2.54mm pin spacing
2 M3 x 15mm nylon screws
2 M3 x 6mm nylon screws
2 M3 x 9mm tapped nylon spacers
1 2-pair (4-wire) sheathed telephone cable (to suit installation)
5 100mm nylon cable ties
Neutral-cure silicone sealant

data is the same for both transmissions before it accepts it as valid. In addition, the encoding selections for the Water Tank Level Meter and the Base Station must match, the water tank level must not be more than 110% and the stop bit encoding must be correct.

Data protocol

The protocol for sending data is as follows: initially, the Water Tank Level Meter sends a 50ms transmission to set up the receiver to be ready to accept data. A 16ms locking signal is then sent, followed by a 4-bit encode signal and the 4-bit tank number.

Next, the 8-bit tank level is sent, followed by the temperature (eight bits with bit 7 as a sign bit), cell voltage (8 bits) and then the 8-bit water level again and the temperature again.

The 8-bit stop code, which has a value of 170 is then sent. These stop bits indicate that the signal is a water tank signal. A different stop bit sequence is used for the water pump control transmission.

Note that the locking sequence is included at the start of each transmission because the oscillator rate is slightly different for each tank selection. In operation, the receiver must lock onto the transmission rate or the data will be read incorrectly.

The data from the 433MHz transmitter is sent at a nominal 1kbits per second. The receiver in the Base Station detects the signal and delivers the same data at its output.

That's all for this month. Next month, we'll show you how to build both versions (Basic and Telemetry) of the Water Tank Level Meter and describe the Base Station. ***EPE***

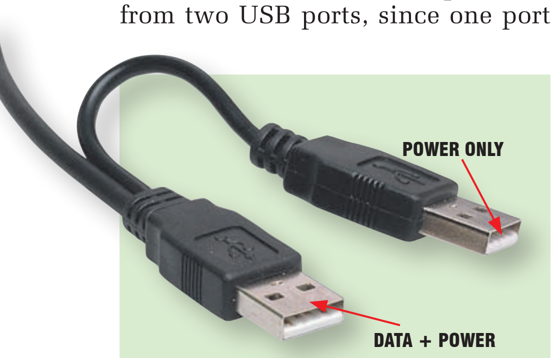
By Greg Swain

USB power injector for external hard drives

A portable USB hard drive is a great way to back up data, but what if your USB ports are unable to supply enough 'juice' to power the drive? The answer is a USB Power Injector.

FOR some time now, the author has used a portable USB hard drive to back up data at work. As with most such drives, it is powered directly from the USB port, so it doesn't require an external plugpack supply.

In fact, the device is powered from two USB ports, since one port is incapable of supplying sufficient current. That's done using a special USB cable that's supplied with the drive. It has two connectors fitted to one end, forming what is basically a 'Y' configuration (see photo).



An external USB hard drive is usually powered by plugging two connectors at one end of a special USB cable into adjacent USB ports on the computer. This allows power to be sourced from both ports.

One connector is wired for both power and data, while the other connector has just the power supply connections. In use, the two connectors are plugged into adjacent USB ports, so that power for the drive is simultaneously sourced from both ports.

According to the USB specification, USB ports are rated to supply up to 500mA at 5V DC, so two connected in parallel should be quite capable of powering a portable USB hard drive – at least in theory.

Unfortunately, in my case, it didn't quite work out that way. Although the USB drive worked fine with several work computers, it was a 'no-go' on my home machine. Instead, when it was plugged into the front-panel USB ports, the drive repeatedly emitted a distinctive chirping sound as it unsuccessfully tried to spin up. During this process, Windows XP did recognise that a device had been plugged in, but that's as far as it went – it couldn't identify the device and certainly didn't recognise the drive.

Plugging the drive into the rear-panel ports gave exactly the same result. The problem wasn't just confined to this particular drive either. A newly-acquired Maxtor OneTouch4 Mini drive also failed to power up correctly on my home computer, despite working perfectly on several work computers.

What's the problem?

That test clearly indicated that the fault lay in my home computer. However, the USB ports on this machine worked fine with my WiFi transmitter, a printer and various flash drives, so what was the problem?

From the symptoms, it was apparent that the USB ports on my home machine were incapable of supplying sufficient current to power USB hard drives, even though the computer is only about three years old and uses a well-known brand of motherboard.

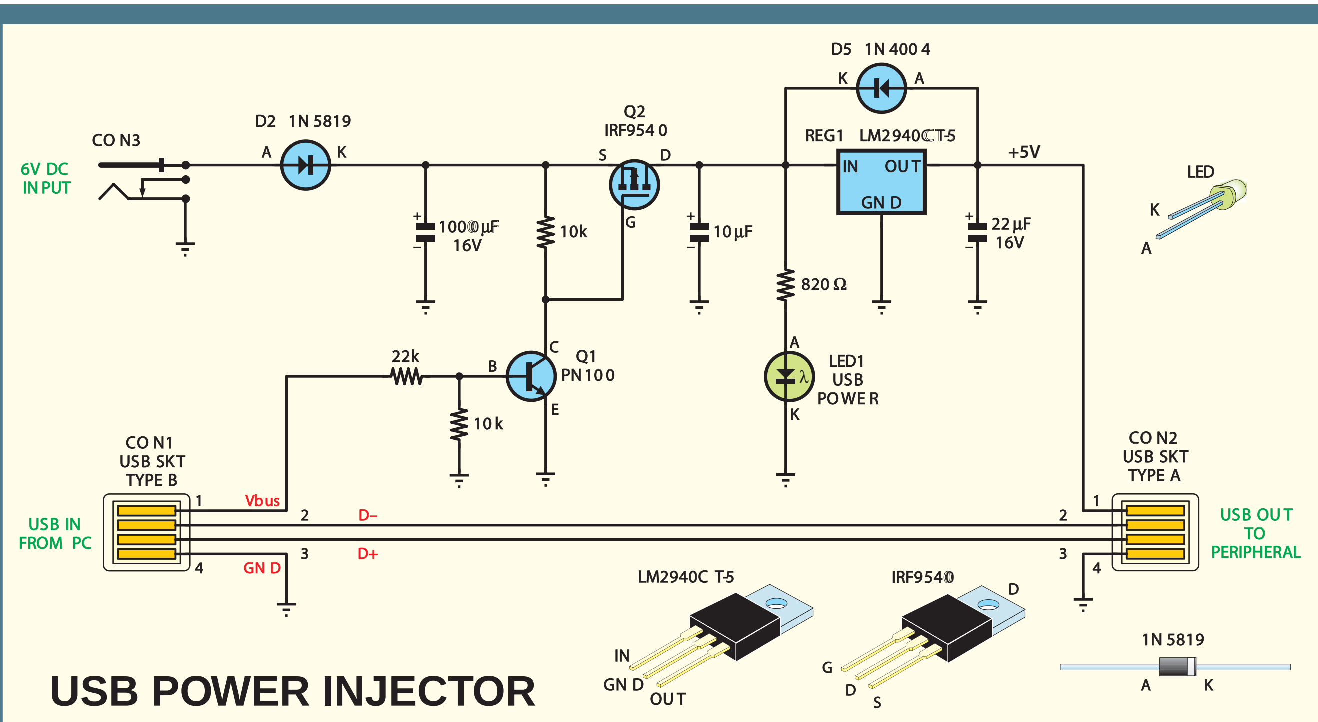


Fig.1: the revised USB Power Injector is essentially a switch and a 5V regulator. The Vbus supply from USB socket CON1 turns on transistor Q1, which then turns on power MOSFET Q2. This then feeds a 6V DC regulated supply from an external plugpack to regulator REG1, which in turn supplies 5V to USB socket CON2.

For some reason, its USB ports were below specification, so it was necessary to find another way to power my USB hard drives.

USB power injector

A powered USB hub would be one way of tackling this problem. However, without knowing the hub's output current specifications, there was no *guarantee* that this would work.

Another option was to use the *USB Power Injector* project published in our Dec '06 issue. This device is powered from an external plugpack and is designed to connect in series between the PC's USB port and the peripheral.

In practice, the device is connected via two onboard USB sockets. When it detects 5V DC coming from the PC's USB port (or from a hub), it switches power from the plugpack through to a 5V regulator, which then powers the peripheral. So the peripheral is no longer powered directly from the PC's USB port, but by the injector instead.

Conversely, the data (D+ and D–) and ground connections are run straight though from the input USB socket to the output socket. Only the Vbus line is broken to switch the regulator on and off, with the regulator providing the new 5V Vbus line.

This seemed to be the way to go, so the original circuit was assembled and teamed with a 9V AC 1A plugpack and it worked. Once connected, the injector could successfully power either USB drive and they could now be used with my home computer.

Note that only the USB plug with both the power and data connections at the 'Y-connector' end of the cable is connected to the USB Power Injector. The connector with just the supply connections is left disconnected.

How do you know which connector is which? Well, sometimes, the connectors are labelled. If not, then the straight-through connector is invariably the one with both the power and data connections.

Alternatively, you can dispense with the 'Y-cable' and use a conventional single-ended cable to connect the drive to the USB Power Injector.

It gets too hot

Unfortunately, that wasn't the end of the story. Although, this arrangement worked, the 5V regulator on the USB Power Injector board quickly became much too hot for comfort whenever power was applied. In fact, it was getting so hot that there was a danger that its inbuilt thermal overload protection circuitry would shut the device down.

USB hard drives like this Maxtor OneTouch4 Mini typically draw between 350mA and 750mA. Used with a 6V regulated DC plugpack, the modified USB Power Injector is ideal for powering this type of drive if your PC's USB ports aren't up to the task.

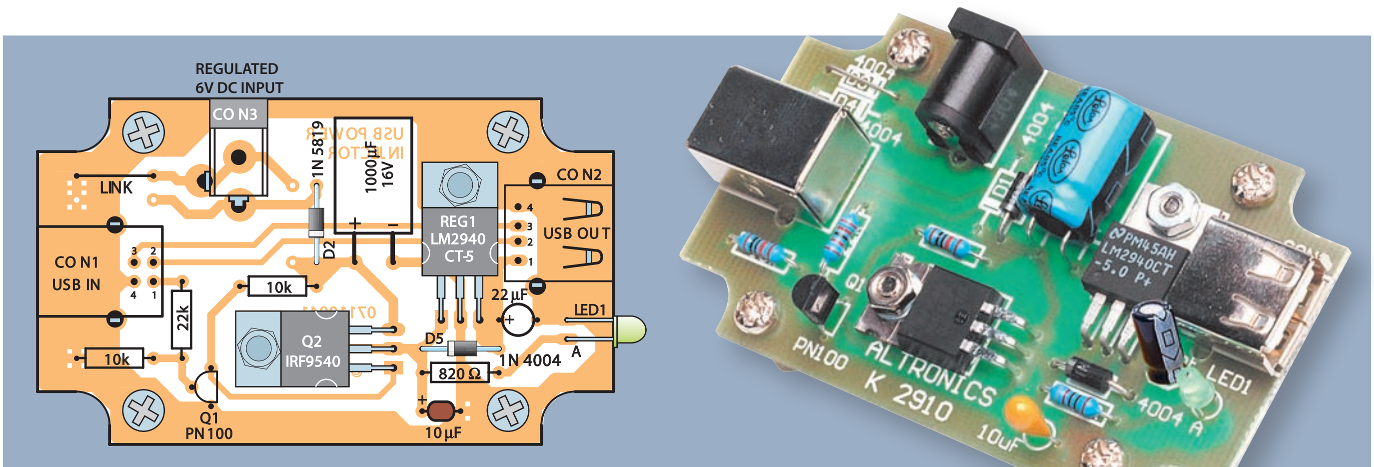


Fig.2: follow this parts layout diagram and the photo at right to assemble the PC board. Don't get Q2 and REG1 mixed up – they look the same!

It's not hard to figure out why. After rectification and filtering, a 9V AC plugpack delivers about 13V DC to the input of the regulator (REG1) which means that there is about 8V across it. In addition, a quick check of the Maxtor drive revealed that it draws between about 350mA and 750mA or more, depending on the amount of disk activity.

In fact, these figures were measured on a DMM, so the peak current draw is probably in excess of 800mA (eg, when the disk is copying large files).

Assuming an average current of 500mA (0.5A), this meant that the regulator was dissipating around 4W (ie, 8V x 0.5A = 4W). No wonder it was getting hot!

No substitution

Substituting a regulated 9V DC plugpack is not the answer either. Although this drops the voltage on the regulator's input to about 7.7V (after allowing for the two diode drops in the bridge rectifier), the regulator still dissipates 2.7V x 0.5A = 1.35W. That's much better than 4W of course, but the regulator isn't fitted with a heatsink and still gets much too hot.

So, as it stood, the USB Power Injector was not really up to the job of powering an external USB drive over any length of time – especially as these drives can draw 750mA or more. In fact, the original project was not designed to supply that sort of current and so was never intended for this particular task.

Keeping it cool

OK, that's the bad news. The good news is that it's easy to make a few simple changes to the USB Power Injector so that it can supply the extra current while keeping its cool.

The trick is to get the dissipation in the regulator right down. We did that by making the following changes:

1) Using a 6V DC 2.2A regulated plugpack instead of a 9V plugpack (we used a switchmode design from Jaycar, Cat. MP-3482);

2) Removing the bridge rectifier and substituting a 1N5819 Schottky diode (a 1N4004 would drop too much voltage)

3) Replacing the 7805 with an LM-2940CT-5 low-dropout regulator and increasing the 100nF ouput capacitor to 22µF to ensure stability.

In practice, the 6V plugpack we used has an output of about 6.1V. The Schottky diode drops this by about 0.4V, while the drop across the switching MOSFET in series with the regulator is negligible at about 0.05V (for 500mA). That leaves about 5.65V at the input to the regulator, which now dissipates just 0.65 × 0.5 = 0.325W (or 325mW).

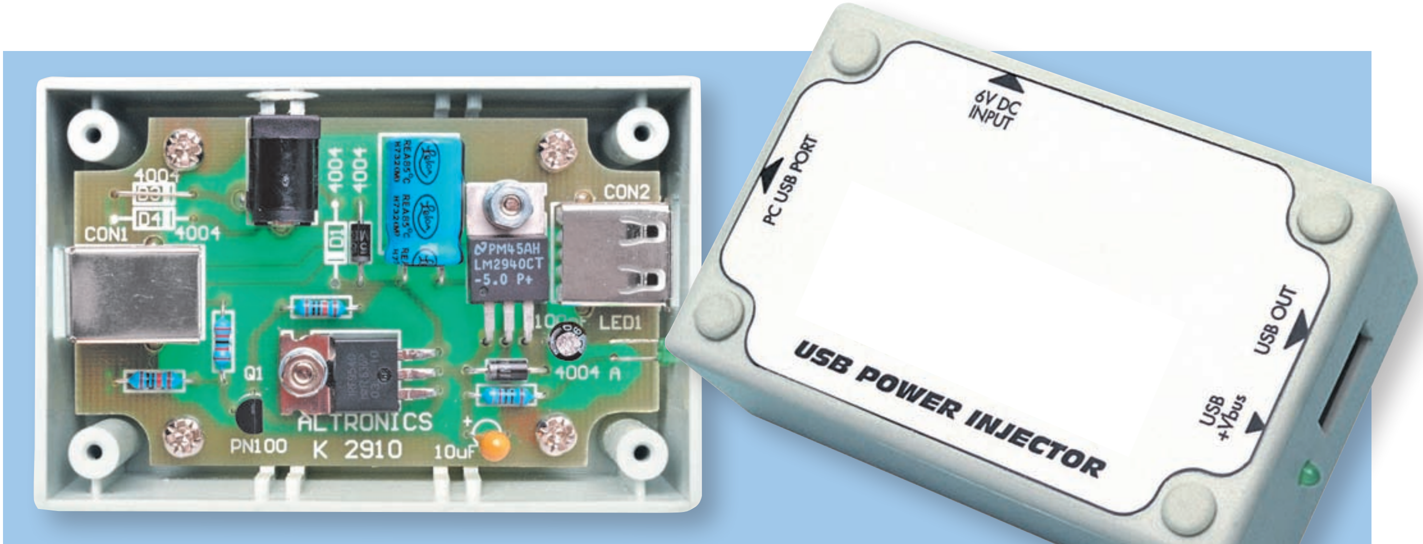
Choosing A Regulated Plugpack Supply

To keep dissipation in the regulator to a minimum, it's important to use a 6V DC regulated plugpack. If you intend powering a USB hard drive, then we recommend the Jaycar MP-3482 plugpack which is rated at 2.2A, although any other 6V DC regulated plugpack rated at 1A or more would also be suitable.

For devices which draw less than say 600mA maximum, then the Jaycar MP-3145 which is rated at 800mA could be used. However, it will be marginal at best for use with USB hard drives which have peak currents of 800mA or more.

Table 1: Resistor Colour Codes

❏	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❏	1	22kΩ	red red orange brown	red red black red brown
❏	2	10kΩ	brown black orange brown	brown black black red brown
❏	1	820Ω	grey red brown brown	grey red black black brown



The PC board is mounted inside the case on four M3 × 9mm tapped spacers and secured using machine screws. Note how the 1000µF electrolytic capacitor is mounted.

That's easily handled by the regulator's metal tab and by the 'earth' (0V) copper pattern at the back of the PC board, which provides a modest amount of heatsinking. In practice, the regulator now runs only slightly warm to the touch when powering a USB hard drive.

Circuit details

Fig.1 shows the revised circuit of the USB Power Injector. As can be seen, power from the 6V regulated DC plugpack is applied via Schottky diode D2. This diode serves two purposes:

1) Provides reverse polarity protection for the circuit

2) Drops the plugpack voltage by 400mV to reduce the dissipation in the regulator (REG1).

A 1000µF electrolytic capacitor is used to filter the resulting 5.6V supply rail, which is then applied to the source (S) of power MOSFET Q2.

CON1 is a USB 'Type B' socket and this is used as the input port on the injector. This is connected to a USB port on the PC (or a hub) via a standard 'Type A' to 'Type B' USB cable. As shown, its two data lines (D+ and D–) are fed straight through to CON2, a 'Type A' USB socket which is used as the output port.

Similarly, CON1's ground pin (pin 4) is connected straight through to CON2's ground pin.

CON2 connects to the USB peripheral (eg, a hard drive) via another standard USB cable. As a result, USB data can pass straight through the injector (ie, between the PC and the peripheral) in either direction.

However, the +5V (Vbus) line from CON1 is not fed through to CON2. Instead, it's used to control transistor Q1.

As shown, the Vbus line drives Q1's base (B) via a 22kΩ resistor. When the input cable is disconnected, Q1's base is held low via a 10kΩ resistor. As a result, Q1 is off and so MOSFET Q2 is also off, and no power flows through to regulator REG1.

Conversely, when the input cable is connected (and the PC is on), +5V appears on pin 1 of CON1 and this turns transistor Q1 on. This pulls Q2's gate (G) low, and so Q2 now switches on and feeds the voltage at the output of D2 through to low-dropout voltage regulator REG1. REG1 in turn provides a nominal +5V output to pin 1 of CON2 to power the external USB device.

Note that when Q2 turns on, it becomes a very low resistance – somewhere around 0.1Ω. As a result, the voltage across it for a current drain of 500mA is just 0.05V.

In addition, when Q2 turns on, LED1 also turns on to indicate that power is present at USB output socket CON2. An 820Ω resistor in series with LED1 limits the LED's current to around 7mA.

Diode D5 protects regulator REG1 from reverse voltage damage when the power is turned off (it's probably not needed with the LM2940CT-5, but was included in the original circuit). The 10µF and 22µF capacitors provide additional filtering to ensure stable operation of REG1.

Construction

The PC board used is the same as for the previous version. It is coded 597, measures 76 × 41mm and is available from the *EPE PCB Service*.

Fig.2 shows the parts layout. Note that the 1N5819 Schottky diode is fitted to the D2 position (instead of the 1N4004 previously used there),

Parts List

1 PC board, code 597, available from the *EPE PCB Service*, size 76 × 46mm
1 UB5 plastic utility box, size 83 × 54 × 31mm
1 PC-mount type B USB socket, (CON1)
1 PC-mount type A USB socket, (CON2)
1 PC-mount 2.5mm DC power socket (CON3)
4 M3 × 9mm tapped spacers
6 M3 × 6mm machine screws
4 M3 × 6mm machine screws, countersink head
2 M3 lock washers
1 50mm-length 0.7mm tinned copper wire (for link)

Semiconductors
1 LM2940CT-5 5V regulator (REG1)
1 PN100 *NPN* transistor (Q1)
1 IRF9540 *P*-channel MOSFET (Q2)
1 3mm green LED (LED1)
1 1N5819 Schottky diode (D2)
1 1N4004 1A rect. diode (D5)

Capacitors
1 1000µF 16V PC electrolytic
1 22µF 16V PC electrolytic
1 10µF 25V tantalum

Resistors (0.25W 1% metal film**)**
1 22kΩ 1 820Ω 10kΩ

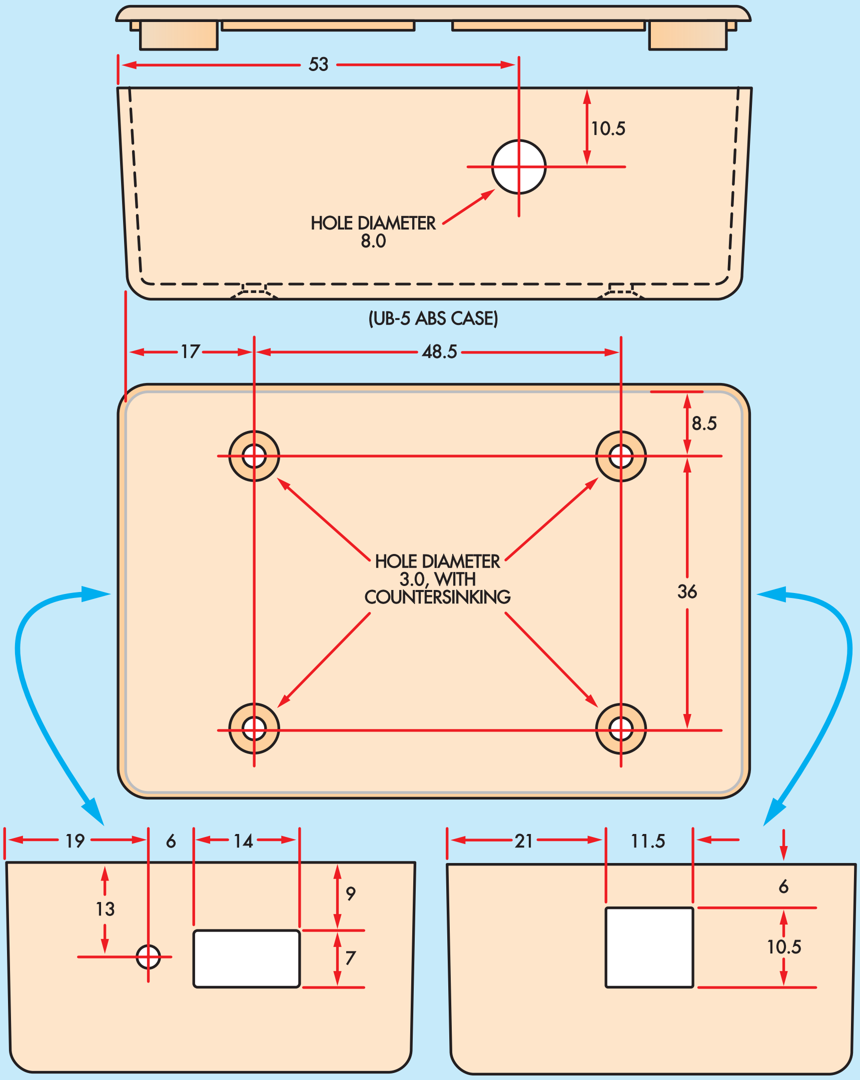


Fig.3: this full-size diagram shows the drilling and cutout details for the plastic case that's used to house the board assembly.

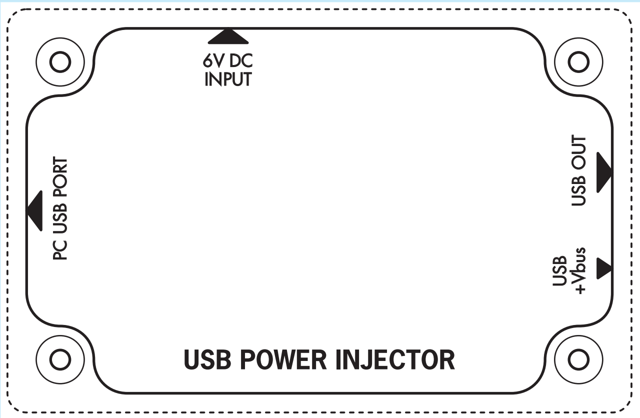


Fig.4: this front panel label can be cut out and attached to the lid of the case. It can be protected using wide strips of clear adhesive tape.

while diode D3 is replaced by a wire link. The other two diodes previously used in the bridge rectifier, D1 and D4, are left out of circuit – see the photos.

Begin the assembly by installing the resistors and diodes (D2 and D5). Check the value of each resistor using a DMM before soldering it into place and take care to ensure that the 1N5819 diode goes in the D2 position. Take care also with the diode polarity.

Next, install the three capacitors. Note that the 1000µF electrolytic is mounted on its side, with its leads bent down through 90° to go through the board holes. All capacitors must be fitted with the correct polarity.

Transistors Q1 and Q2 can go in next. Q1 is straightforward – just push it down onto the board as far as it will comfortably go and check its orientation before soldering its leads.

Q2 is mounted with its metal tab flat against the board. First, bend its leads down by 90° about 5mm from its body, then fit it to the board and secure its tab using an M3 × 6mm machine screw, nut and washer. Q2's leads can then be soldered and trimmed.

Note: don't solder Q2's leads before securing its tab. If you do, you risk cracking the PC board tracks as the mounting screw is tightened.

Regulator REG1 is mounted in exactly the same manner as Q2. As before, be sure to secure its metal tab before soldering the leads.

LED1 is next on the list. It's soldered in place with its body about 11mm above the PC board, after which it is bent down at right angles about 4mm above the board. This is done so that it will later protrude through the end of the case.

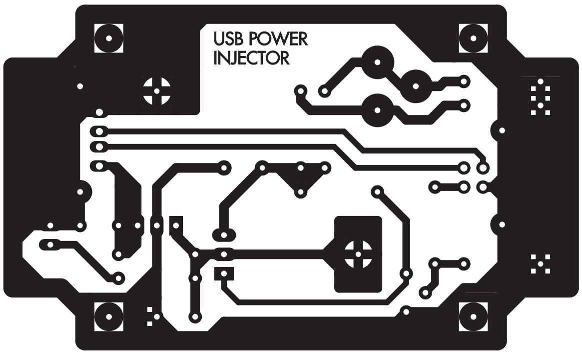
The PC board assembly can now be completed by fitting connectors CON1 to CON3. Make sure that these all sit flush against the PC board before soldering their leads.

Final assembly

The assembly is housed in a standard UB5-size plastic utility box. This box requires rectangular cutouts at either end to provide access to the two USB connectors (CON1 and CON2), plus a 3mm hole in the end next to CON2 to allow LED1 to protrude.

An 8mm hole must also be drilled in one side of the box to provide access to the DC power socket (CON3). And finally, four holes are drilled in the base to mount the PC board. These holes are countersunk from the outside of the case, to accept countersink-head machine screws.

Fig.3 shows the drilling details. Note that the sections in this diagram are all full-scale and can be used as drilling templates. Once the holes have been drilled, attach four M3 × 9mm tapped



Check your PC board carefully against this full-size etching pattern before installing any of the parts.

spacers to the PC board, then secure the assembly inside the box using four M3 × 6mm countersink screws.

Checkout time

The unit can now be checked for correct operation. To do this, apply power from a 6V DC regulated plugpack and check that LED1 lights when you connect CON1 to your PC's USB port. The LED should go off again if the cable to CON1 is disconnected.

Next, check the voltage on the OUT pin of the regulator (see Fig.1). This will probably be around 5.2V to 5.3V unloaded, but should be very close to 5V if a load (eg, a USB hard drive) is connected. The USB specification is for a voltage in the range of 4.75V to 5.25V, so make sure it is in this range.

The unit is now ready to power your USB hard drive or other peripheral. All that remains is to fit the lid and attach the front-panel label (Fig.4).

Finally, be sure to leave the power-only connector on the cable to the hard drive disconnected when using the USB Power Injector. Do NOT plug it into a USB port on your computer. ***EPE***

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What do you do for an LED flasher now that the LM3909 is no more?

LM3909 Replacement Module:

it's even more versatile!

by
Thomas Scarborough

The LM3909 was a legendary IC, which the designers (National Semiconductor) modestly described as an 'LED flasher/oscillator'. Its popularity was surely due both to its great simplicity and versatility. It could flash an LED from a wide range of voltages, at a wide range of frequencies. It could also flash LEDs in parallel, could produce a tone in a loudspeaker, trigger a triac or pulse an incandescent bulb – among other things. Sadly, the LM3909 has been discontinued, and it is now very difficult to find.

THE module shown here is designed to do just about everything that the original LM3909 did – and more.

There are a couple of differences – the most obvious one is that the module is quite a bit larger than the DIP-sized LM3909.

The supply voltage is much more flexible at 3V to 18V, compared to the LM3909's 1.15V to 6V. Current consumption may be as low as 100µA, rather than the LM3909's typical 0.55mA. Pulse width may be controlled more easily than it could with the LM3909.

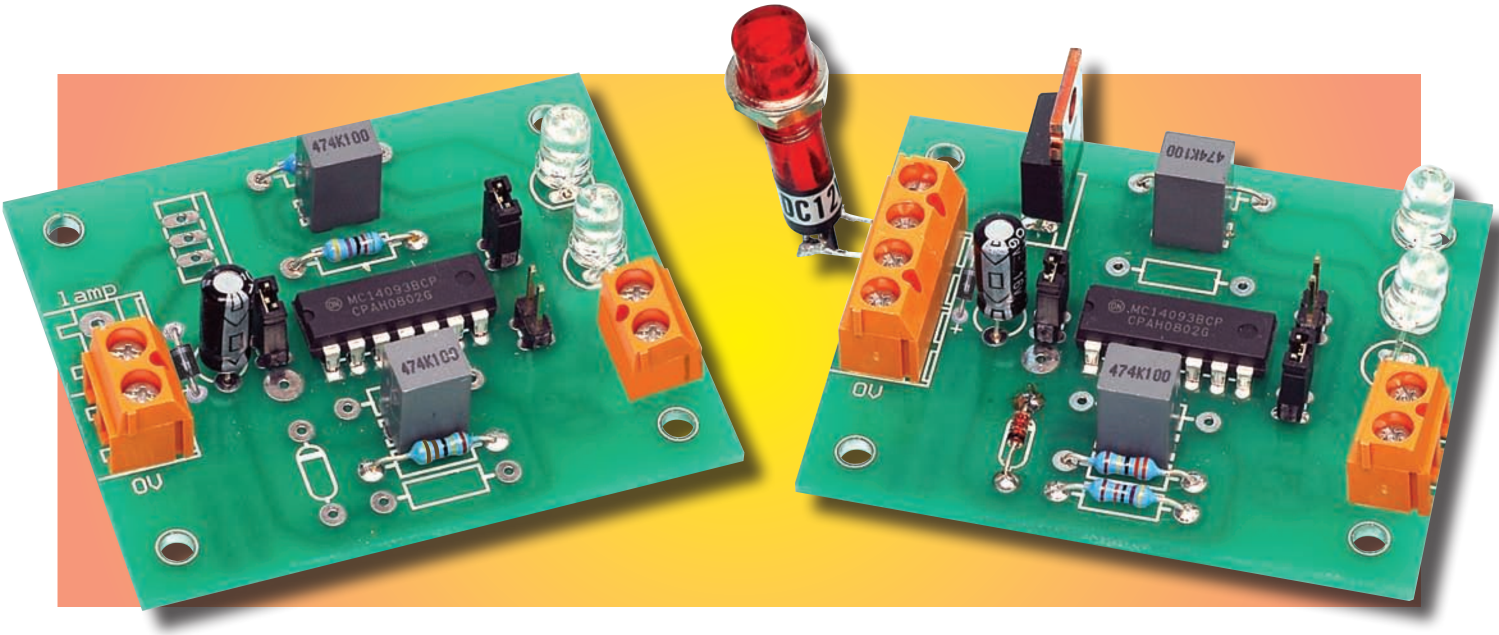
Furthermore, this circuit can pulse two LEDs alternately. It will also serve, among other things, as a quartz clock driver and continuity tester. Rather than present a host of similar circuits, however, a single module is shown here, along with a table showing how the module can be used in a variety of ways.

Circuit description

The circuit diagram for the LM3909 Replacement Module is shown in Fig.1. IC1a is a Schmitt RC oscillator or 'clock generator'. Only capacitor C1 can be regarded as a fixed part of the oscillator; R1, R2, R_X, R_Y and D2 are all components which can be changed to allow the module to perform in different ways.

The output of the oscillator charges and discharges capacitor C2 through IC1b, connected as an inverting buffer. The charge on C2 then controls IC1c. When the output of IC1c is combined with the the output of IC1d (which is the inverted output of IC1a), brief pulses are sent in opposite directions between IC1c and IC1d. Depending on their direction, these pulses will cause either LED1 or LED2 to flash.

Resistor R_X sets the frequency of the flash, while R_Y sets the pulse width (or 'on' time) of one or both of the LEDs. Resistor R_B limits the current through the LEDs to safe values.



Two of the many possible versions of the LM3909 Replacement Module – on the left, the alternate LED flasher with Link 2, R_X at 4.7MΩ, R_B at 1kΩ, no R2, and R_B (hidden behind capacitor at top) at 47kΩ. On the right is the LED/bulb flasher, with Link 3, R_X at 2.2MΩ, R2 at 470kΩ (in series with its diode), R_B at 1kΩ and no R_Y. Note the MOSFET lamp driver (Q1) is also in place on this PC board. For most of the time, Link 1 stays in place (the circuits won't work without it).

Link 1 is a switch which either enables (when connected to +V) or disables the oscillator (tying pin 1 to 0V via resistor R1). In all except one case, Link 1 stays in place unless you want to stop the circuit oscillating. In fact, Link 1 could be replaced by a switch if you want to make it even more convenient.

Link 2 and Link 3 can be changed to make their respective gates operate in different ways, in turn affecting the operation of the module. This is what gives the module much more flexibility than the LM3909 it is replacing.

Link 2 is used where a short pulse width is required, and Link 3 is used where a square wave is required.

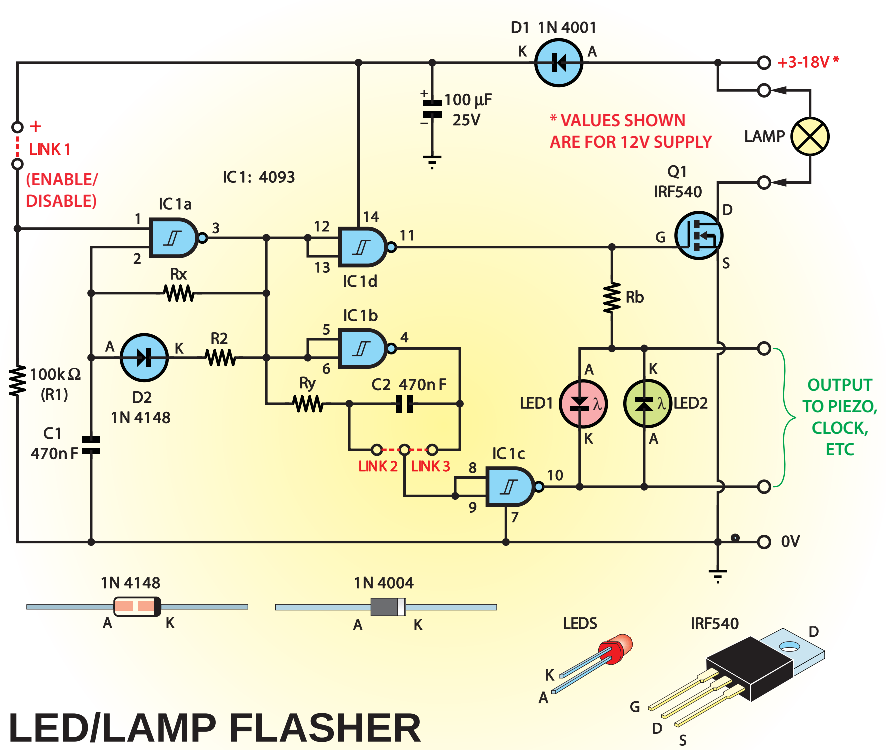


Fig.1: Where the LM3909 had just about everything inside the DIP package, the replacement module requires a few more components – but it does more than the LM3909 ever did!

Options

Various possibilities are shown in Table1. Component values in this table are selected for 12V operation and will likely need to be modified for other supply voltages.

One of the other features of this module, which you didn't get (as much) with the LM3909, is that it allows significant experimentation and modification of values.

With the exception of R_B, changing any of the resistors (even going down to 0Ω) will not cause any damage to the module (R_B limits LED current through the LEDs and should never be less than about 470Ω).

Finally, if LEDs are wired in parallel, these should really have individual current-limiting resistors, the combined resistance of which should not be less than about 330Ω.

Power supply

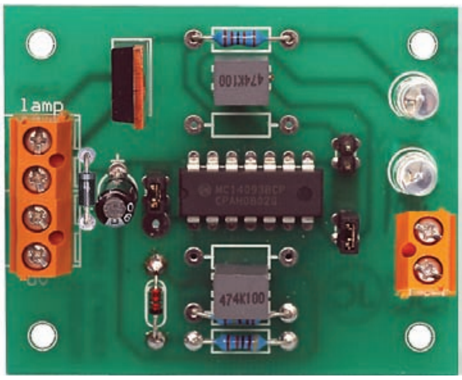
As mentioned earlier, one of the features of this module is its wide supply voltage range (3V to 18V). This is connected via a terminal block on the left side of the module, which is in turn protected against incorrect polarity by diode D1 and is decoupled (smoothed) by the 100µF capacitor.

This capacitor is specified as 25V to allow up to an 18V supply; if you are ***never*** going to use a supply greater than 12V, a physically smaller 16V capacitor can be used.

The lamp, its terminal block and the lamp driver (MOSFET Q1) are optional

Table1: LED Flasher Modules – Component Selection Guide

Application	R_X	R_Y	R_B	R_2	Links	LEDs	Notes
LED Flasher	2.2MΩ	47kΩ	1kΩ	None	LINK 1 IN LINK 2 IN	LED1	
Alternate LED Flasher	4.7MΩ	47kΩ	1kΩ	None	LINK 1 IN LINK 2 IN	LED1 LED2	
Micropower Alternate LED Flasher	4.7MΩ	10kΩ	2.2kΩ	None	LINK 1 IN LINK 2 IN	LED1 LED2	Ultrabright LEDs are required here. A 47kΩ resistor is wired in series with the power supply's +V. The circuit draws about 100μA. Remove resistor R1 to minimise current drain.
Square Wave Alternate LED Flasher	4.7MΩ	None	1kΩ	None	LINK 1 IN LINK 3 IN	LED1 LED2	
Modified Square Wave LED/Bulb Flasher	2.2MΩ	None	1kΩ	470kΩ and diode	LINK 1 IN LINK 3 IN	LED1	The 470kΩ and diode are wired in parallel with R_X. Depending on the diode's orientation, the LED will be illuminated longer or shorter than half a complete cycle. By making IC1d pin 11 drive a MOSFET, this configuration may be used to flash an incandescent bulb.
Modified Alternate LED Flasher	4.7MΩ	47kΩ	1kΩ	1MΩ and diode	LINK 1 IN LINK 2 IN	LED1 LED2	The 1MΩ and diode are wired in parallel with R_X, yet the diode's polarity is immaterial here. The effect is a pulsing of the two LEDs 'in twos'.
Quartz Clock Motor Driver	10MΩ variable	150kΩ	470Ω	None	LINK 1 IN LINK 2 IN	Stepper motor	R_Y, R_B may need to be altered, depending on the quartz clock's stepper motor's characteristics. This is merely an experimental circuit, since an RC timer will not provide good keep time.
Externally Pulsed Quartz Clock Motor Driver	None	150kΩ	470Ω	None	LINK 1 IN LINK 2 IN	Stepper motor	The external pulses need to match the supply voltage of the module. These may need to be further lengthened. This may be done by wiring a diode between the source of the pulses and IC1a pin 2, with the cathode to pin 2 and a resistor in parallel with C1 (try 2.2MΩ).
Continuity Tester	2.2kΩ	None	None	None	LINK 1– wired to 0V via a 1MΩ resistor (see note)	Piezo sounder	The piezo sounder is wired to the sounder outputs for LED1. The continuity tester's leads are taken from the LINK1 terminals. R1 may be increased to 1MΩ for the continuity tester; alternatively 1kΩ to avoid obtaining a signal for high impedance continuity.



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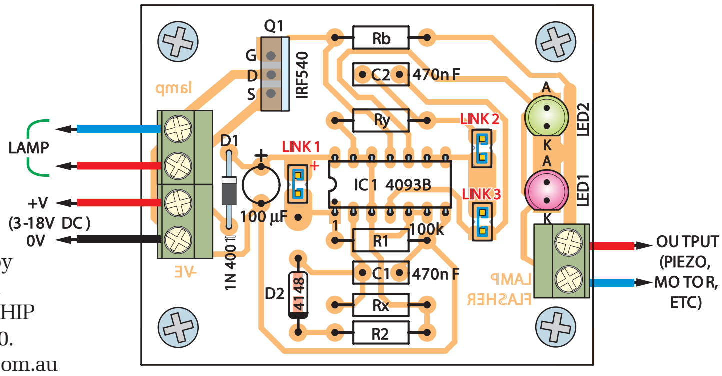


The same-size photo above matches the component overlay at right. The photo is of the Alternate LED Flasher. While this PC board might look like a double-sided type, it's not: it was produced on a panel which included a double-sided board, hence pads also appear on the top side, along with pads and tracks on the bottom side.

Parts List

1 PC board, code 752, available from the *EPE PCB Service*, size 62mm × 50mm
3 2-way PC-mount terminal blocks
3 2-way header pin sets
1 4093 quad Schmitt NAND gate
1 IRF540 MOSFET (Q1 – optional)
1 1N4004 power diode (D1)
1 1N4148 small signal diode (D2)
2 5mm LEDs, colours as required
1 small incandescent lamp, to suit supply voltage (optional)

Capacitors
1 100μF 25V radial electrolytic
2 470nF MKT metallised polyester

Resistors (0.25W 1% metal film)
1 100kΩ (R1)
Other resistors to suit application – see component selection

– if you don't want to drive a lamp, simply leave them out.

Construction

The printed circuit board component layout is shown above. This board is available from the EPE PCB Service, code 752. This project could hardly be simpler – just mount the components as shown on the overlay, also using the photograph as a guide.

Start with the terminal blocks. For most uses, a two-way block will suffice on each side of the PC board (the four-way on the left-side is only required for the incandescent lamp driver). Follow these with the three header pin sets (for Links 1, 2 and 3), then the resistors and capacitors, next the LEDs, the MOSFET (if required) and finally diode D1 and IC1.

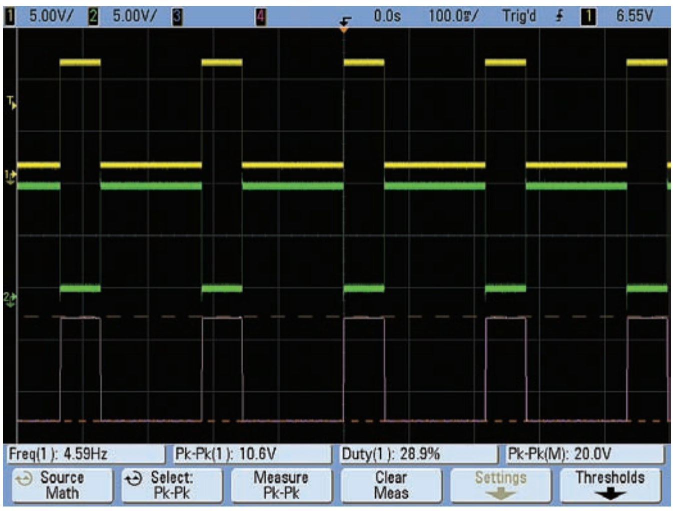
Diode D2 could be left out if you don't want to build the lamp driver or modified alternate LED flasher, but given its low cost, it might as well be included. Without resistor R2 in place, it will have absolutely no effect.

Note that all components except the resistors and the two 'block' capacitors are polarised – the circuit won't work if you put them in the wrong way around (and you could damage them).

Also, be very careful when soldering in components with close lead spacing (especially the IC). It's very easy to bridge across adjacent pads and once again, this will stop the project working and could cause damage.

If you want to experiment with different values, here's a tip: solder in some PC stakes for all resistor values which you might want to change (R2, R_B, R_X and R_Y).

It's a lot easier to tack resistors across the stakes rather than solder them into the PC board and take them out again (besides, it's easy to damage the PC board tracks with too much soldering and desoldering). ***EPE***



This shows how the two outputs from IC1d (yellow) and IC1c (green) add to give double the drive signal to the LEDs (white trace).

The flasher board set up for a 50% duty cycle flasher. In fact, it is not quite 50%, due to the differing positive and negative switching thresholds in the gates.

Recycle It!

BY JULIAN EDGAR

The multi-purpose tape machine

Old tape-based answering machines can now be picked up for next to nothing, or perhaps you've got one stashed away in the cupboard. Here are few ideas of how you can put them to good use.

Tape-based telephone answering machines are now almost given away free wherever electrical junk is discarded. So what can you do with them? As described in the text, there are plenty of novel messaging applications.

LOOK at these pictures – seen one of these before? If you said, 'Yeah, of course I have – it's just an old telephone answering machine', then think again. What you have in front of you is really a multi-purpose tape machine – one that's able to leap tall buildings, etc...

Well, not quite, but it's certainly capable of forming the basis for some interesting 'no-cost' projects.

Want some examples? OK, you live on a main road where there's a constant stream of charity collectors and fervent religious followers continually coming to your door. You're not against giving to charities, but you'd prefer to do it on your terms not theirs, and your religious beliefs are already firmly held. Here's where that old answering machine comes in – you can use it to get rid of them.

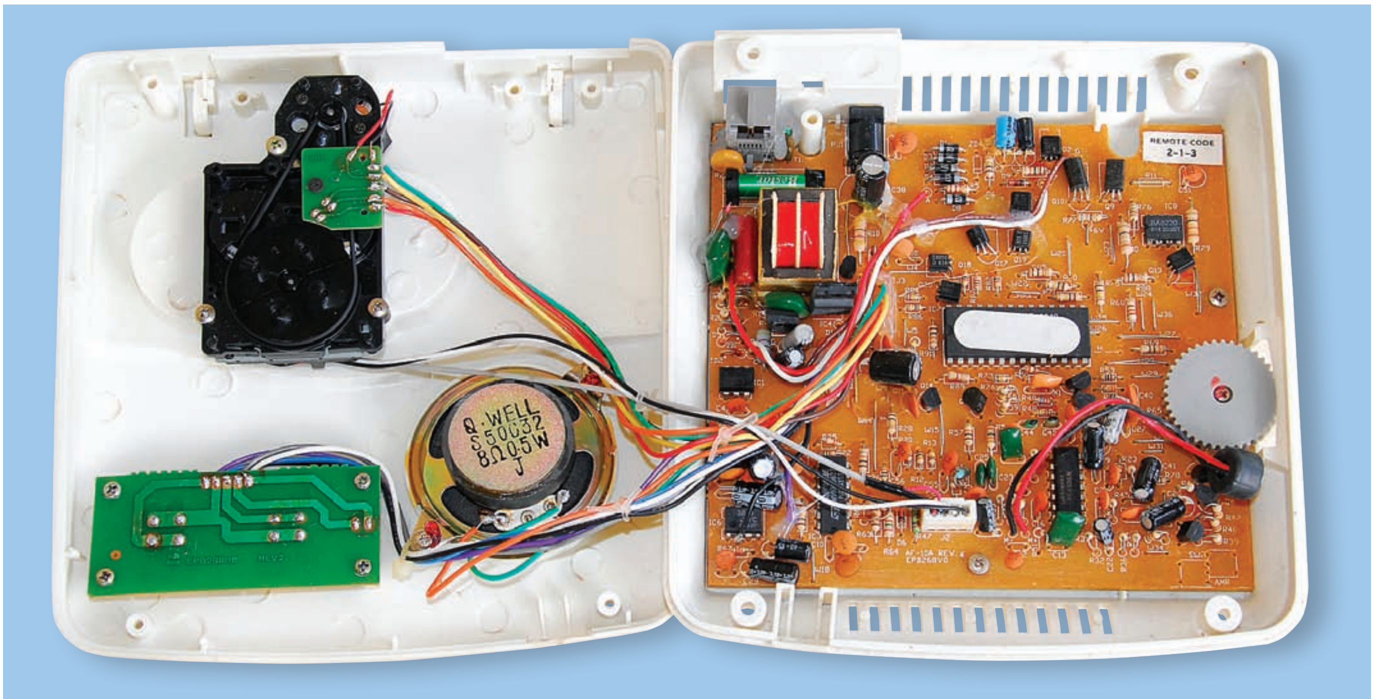
Sound-off

Imagine this: you're just settling down to build a brand new electronic kit and the doorbell rings. You just know it's not anyone you want to talk to, so you just press a button that's linked to the answering machine. One press is all that's needed and the message is clearly and loudly played to those door squatters: 'Thank you, but I am not interested in anything that you have to sell or collect. Please leave my property forthwith. This is a recording so don't bother answering back. The guard dog will be automatically released in 30 seconds!'

And if you really want to drive the message home, you can have a harangue lasting up to a minute! Ha! – that'll show 'em.

Well, you get the idea, although in practice you might want the message to be a bit more 'courteous' than that.

In short, anywhere that a recorded message is needed at the push of a



As this photo shows, accessing the 'Outgoing Message Record' (OMG) pushbutton wiring, the speaker and the microphone is easy. It's then straightforward to turn the old answering machine into a voice-warning annunciator, a talking burglar alarm, or even a sound generator in a model train layout.

button, this machine can be used for it. And if you're thinking, 'why use a tape machine in this day and age?', just consider the available message length and the cost. First, the machine costs nothing (or almost nothing) because you already had it stashed away in a cupboard, or you simply scrounged it. And second, some tape answering machines can run a three-minute message!

Answering machine

The unit used was the Shimasu F-7010. It was originally listed in 1996 catalogues for around £30, and can now be picked up at garage sales, secondhand stores and the like for a pound or two. The unit shown here came from a municipal tip, so it cost nothing at all.

Recording and playing a message

After you've made sure that there's a tape inside the machine and it's powered up, follow these steps. To record the message, press the OGM (out-going message) button until the LED flashes. Record your message and release the button. To play what you have just recorded, simply momentarily press the OGM button – it really can't get much easier than that. (Note: the above steps are for the Shimasu F-7010 answering machine. Other tape-based answering machines may have differences, but they all work in a similar fashion.

A few uses

There are plenty of uses that can be made of a warning message tape. Some are fun and others are more serious. Here's three examples:

1) Model railway sounds – the big advantage over generic sound simulator chips is that you can actually record real train sounds!

One example is the sound of 'ding-dong' level crossing bells – you can record these (perhaps with another tape recorder) and then the sound will be as realistic as possible. On the layout, the tape machine can be triggered by a reed switch activated by a magnet in the approaching train.

2) Interior car alarm – how would you feel as a thief if the owner started warning you ominously? 'Warning! Warning! This car is being stolen. GPS tracking has been enabled. Warning! Warning!' It's easy to do if the tape machine is triggered by a momentary input. Feed this message through a cheap car audio amplifier and an external horn speaker and very few thieves would proceed!

3) Industrial warning – this could be used to explain an 'idiot light'; eg, 'Low oil pressure has been detected. Turn off the engine immediately. Damage will result if the engine keeps running. This is the low oil pressure alarm'.

Modifications

Very little needs to be done to the machine to modify it for its new role – in fact, maybe nothing at all. For most applications, where the machine will be triggered remotely, it's a case of opening it up and then connecting a new momentary pushbutton switch (or reed switch, or relay contacts) via flying leads in parallel with the 'OGM' button.

To improve the recorded sound, you may want to remove the microphone from the case and reposition it, so that your voice is recorded more clearly. The playback also benefits substantially from a larger, more efficient speaker. If you want to get really loud, there's nothing stopping you adding an amplifier. The volume control on the side of the answering

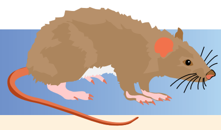
The unit we used was the Shimasu F-7010. It was originally listed in a 1996-97 catalogue for £30, but it or something similar can now be picked up at garage sales, secondhand stores and the like for a pound or two. We got ours from a municipal tip, so it cost nothing at all.

machine should be set to match the amplifier's input level.

Don't forget that cleaning the tape head (use methylated spirits and a cotton bud) and using a new tape can also appreciably lift the sound quality.

Finally, don't skimp on the quality of the message. For example, in the case of a burglar alarm warning, there's nothing to stop you adding police sirens and running foot-steps as background audio to the warning message. That'll really scare 'em! ***EPE***

Rat It Before You Chuck It!



Whenever you throw away an old TV (or VCR or washing machine or dishwasher or printer) do you always think that surely there must be some good salvageable components inside? Well, this column is for you! (And it's also for people without a lot of dough.) Each month we'll use bits and pieces sourced from discards, sometimes in mini-projects and other times as an ideas smorgasbord.

And you can contribute as well. If you have a use for specific parts which can easily be salvaged from goods commonly being thrown away, we'd love to hear from you. Perhaps you use the pressure switch from a washing machine to control a pump. Or maybe you have a use for the high-quality bearings from VCR heads. Or perhaps you've found how the guts of a cassette player can be easily turned into a metal detector. (Well, we made the last one up but you get the idea . . .)

So, if you have some practical ideas, do write in and tell us!

TEACH-IN 2010

LADDER LOGIC PROGRAMMING FOR THE PIC MICRO

Part 6: Customising and Extending the Software

By Walter Ditch

The first five parts of this series focused on using the PLC software in its supplied form, with each instalment concentrating on a different aspect of ladder-logic-based design. If you have been following the series, then by now you should have a good understanding of the concepts involved, and be comfortable writing simple ladder-logic-based PIC programs of your own.

You may soon find yourself wanting to modify and extend the software to suit the requirements of new applications and scenarios. This becomes particularly true in embedded control applications, where PIC micros may be deployed in situations greatly different to those encountered by a typical PLC.

With this in mind, this final instalment looks at a variety of options for reconfiguring, optimising, and extending the software. Topics considered here are grouped into the following three main areas:

1. Understanding and modifying default settings
2. Optimising program code
3. Extending the PLC software.

The good news is that the PLC software is easy to customise or even extend, as we will see shortly.

All required program files for this series are available from the Library > Tutorials section of the *Everyday Practical Electronics* website (**www.epemag.com/**). The ZIP file supplied with this final part of the series is rather special, since it includes a new version of the PLC software (Version 1.1.0), which incorporates all customisation extensions discussed here, plus all program listings and other supplied files from the entire series. Once this file is installed, you will be able to try out the examples from Parts 1 to 6, even if you have not previously downloaded files associated with earlier parts of the series.

As discussed previously, you should use the freely available MPLAB IDE software to assemble the program examples. This may be downloaded from the Microchip website (**www.microchip.com/mplab/**). In order to run the programs, you will need a suitable PIC development board, fitted with one of the supported PIC microcontroller types, or simulation software such as Proteus VSM from Labcenter Electronics.

Changing default settings

You may want to review and change default settings, either to suit available PIC-based hardware, or to meet the requirements of a new design. (If you are happy with the default settings, as supplied with the software, then you may prefer to skip this section and come back to it later.)

Each PLC header file is preconfigured with a variety of sensible defaults, which allows you to get your programs up and running with the minimum of fuss. You can review and change these default settings by loading the appropriate header file into a text editor such as Microsoft Notepad. Major configuration options include input/output port direction, the watchdog timer, plus configuration and option register settings.

Should you decide to modify any settings, the first step is to ensure you have a backup copy of the original header file, allowing you to revert back if required. You might, for example, create a subfolder to contain your custom project, placing a copy of the original header file into your new folder. Any assembly language files placed in this new folder will make use of the custom header file, when assembled.

Reviewing input/output port settings

All supported PIC microcontrollers, with the exception of the 16F887, are configured to use Port A as an input port and Port B as an output. Higher order bits of Port A are allocated for use by the MCLR (master clear or external reset) pin, and by an optional external oscillator. This gives us a maximum

of five input bits and eight output bits for interfacing to external hardware.

Should this be inadequate, then one option would be to use a PIC16F887 microcontroller, which is configured by default with 20 input bits (Ports A, B and E), plus a further 16 output bits (Ports C and D). If the allocation between inputs and outputs be inappropriate, then an alternative might be to edit the port configuration section of the appropriate header file, as we will discuss shortly.

Whichever PIC is chosen, the direction of the port is defined by first writing a configuration byte to the appropriate 'tristate' register (TRISA, TRISB, TRISC, TRISD, or TRISE, with the final letter indicating the port name). Placing a '1' into an appropriate bit of the tristate register configures the same bit of the associated port as an input, while a '0' sets that bit as an output. As an example, Listing 6.1 shows a slightly simplified extract of the port configuration section of the PIC16F627 header file.

```
setports
        movlw   0x1f    ; Set bits 0-4 as inputs (1 = input, 0 = output)
        movwf   TRISA   ; Set TRISA register (Port A = all inputs)
        movlw   0x00    ; Set bits 0-7 as outputs
        movwf   TRISB   ; Set TRISB register (Port B = all outputs)
```

Listing 6.1. Configuring PIC16F627 port directions

(The appropriate section of the file may easily be found by searching for the 'setports' label.)

Clearly, it is not too difficult to change the default port settings — simply change the values written into the appropriate tristate registers, as required. However, you should first check the appropriate data sheet, just to make sure that the affected port bits have no special I/O restrictions. (Bit RE3 on the PIC16F887, for example, cannot be configured as a general purpose output.)

Using the watchdog timer

Microcontrollers may often be used in electrically noisy environments, leading to the possibility of a software 'crash'. Clearly, the main defence against electrical noise should be good electrical design. However, the watchdog timer (WDT) feature provides a useful backup, causing the microcontroller to be automatically restarted if it fails to respond in a predetermined time period.

The basic idea is that the main program scan loop should contain a 'clear watchdog timer' command, which is called many times per second, thus preventing an automated system reset. In the event of a crash, then the main program loop stops running, the WDT expires and the system is automatically restarted. (Refer back to Fig.1.3 (Pt.1 Nov '09) and associated text for more information regarding the scan loop and program execution.)

You don't need to do anything in order to use the WDT feature, as this has been enabled within the header file by setting the appropriate configuration register bit. The first instruction in the scan loop is a clear watchdog timer command, which prevents an automatic reset as long as the scan loop is running.

WDT configuration settings are fairly basic, being largely the processor defaults. The nominal timeout with the PIC16F627A, for example, is 18ms with no prescaler, so there should not be a problem as long as the time for one scan loop is less than this. As a check, assuming 1kb of program memory and a 4MHz oscillator (1μs per typical instruction), then the maximum time for one scan loop would be around 1ms.

User configuration options include disabling the WDT, by clearing the appropriate configuration register bit, or changing WDT defaults. It is well worth reviewing the datasheet for WDT options, as some microcontrollers have a dedicated WDT configuration register. However, on a cautionary note you should generally avoid allocating a pre-scaler to the WDT, as this may affect operation of the PLC software's high speed oscillator register (OSCH).

Modifying device configuration options

Each header file contains a range of default configuration settings, which have been selected to suit the majority of users. The exact options available vary from one microcontroller to another, but typically involve one or more 'configuration words', an 'option' register, plus other miscellaneous registers. Register-based settings configured via header files include:

- PIC16F627A, PIC16F628A, PIC16F648A – configuration word, OPTION, INTCON, PIE1 and CMCON registers
- PIC16F88 – configuration words 1 and 2, OPTION, INTCON, OSCCON, SSPCON, CMCON, ANSEL and ADCON0 registers
- PIC16F887 – configuration words 1 and 2, OPTION, INTCON, PIE1, CMCON, PCON, ANSEL, WPUB and IOCB registers

Advanced users may wish to review and change these options, but the defaults should suit the majority of readers. The main aim is to ensure consistent settings across all supported microcontrollers, as originally summarised in Table 1.2 (Part 1). This includes oscillator, timer and interrupt configuration, plus associated hardware settings.

Clearly, software portability between microcontrollers has been prioritised over the enabling of device specific options, such as pull-up resistors, comparators, and A/D converters. However, this is also a potential area for future experimentation!

In the event that your programs fail to operate on available hardware, then oscillator configuration might be a prime suspect, as set in the configuration register area. These register settings are also a key area for review, should you wish to adapt the software to run on a different PIC microcontroller.

This first section has focused on understanding and modifying default configuration settings. The next part introduces a number of simple techniques which may be used to make your programs smaller, faster and more effective. The third and final section will conclude the series by looking at the development of custom extensions to the PLC software.

Optimising program code

This section considers some relatively straightforward ways to optimise your programs, including:

- Reducing program size
- Creating user defined variables
- Mixing assembly language and ladder logic.

```
include "16F887.PLC"  ; Defines PLC instructions

putr    PORTA, PORTC  ; Transfer Port A to Port C

ld      PORTB, 0      ; Read Port B bit 0
out     PORTD, 0      ; Output to Port D bit 0
ld      PORTB, 1      ; Read Port B bit 1
out     PORTD, 1      ; Output to Port D bit 1
ld      PORTB, 2      ; Read Port B bit 2
out     PORTD, 2      ; Output to Port D bit2

                      ; etc.

endp                  ; End of PLC program
```

Listing 6.2. Comparing bit and byte oriented problem solutions (Lst6_2.asm)

Methods of reducing program size

Even the simplest of ladder logic programs is likely to use 130 to 180 program words when assembled, due mainly to the overhead introduced by the header file. This should not be a problem in most scenarios, since supported PIC microcontrollers are available with program memory sizes in the range 1 to 8kwords. (Refer back to Table 1.2 for details of program memory sizes.)

A simple way to keep track of program memory usage is to read the summary information at the end of the assembler 'listing' file (the file having a '.lst' file extension). An example is shown below for the PIC16F887 microcontroller.

Program Memory Words Used: 181

Program Memory Words Free: 8011

While it is vital to keep track of the size of your assembled machine code program, it is equally important to keep your source code files concise and yet easy to understand. It is always a good idea to make liberal use of comments, in order to explain the operation of your program. These comments will help others to understand your programs, and in any case will be removed at assembly time.

The large number of macro definitions in the header file will not have any effect on the program size, as these will only be assembled if they are actually used. However, it is worth noting that additional customisation features introduced with Version 1.1.0 of the software have added approximately 80 program words to the minimum program size, due mainly to the use of lookup tables for code conversion (more on this later).

One possibility for code simplification might be the use of a single byte-oriented command in place of several bit-oriented commands. A single 'puti' or 'putr' command, for example, might perform the same task as several 'ld' and 'out' instructions (up to eight of each). As an example, Listing 6.2 shows two alternative ways to transfer data from an input port to an output port.

Another possibility for moderate code simplification is to make direct use of the output produced by a previous command as the input to the next. This approach is used routinely in ladder logic programs, but can also offer an alternative to manually reading the status bit value of a previous command.

The key to understanding this approach is to realise that the majority of commands leave their result, or their status bit, in the Working register (W) of the PIC micro. This value is either used immediately by the next program statement, or it is overwritten. An obvious example of this approach is the 'ld' command, which simply leaves its inputted value in the least significant bit of the W register. A corresponding 'out' command takes this value from the W register, sending it to the specified destination. Less obviously, other commands such as counters, timers and shift registers all offer similar functionality, giving the possibility of simplification, with careful ordering of commands.

Recall, for example, that Listing 3.8 (Jan '10) used this technique to link or 'chain' multiple shift registers, with the data shifted out by a previous command being left in the W register, automatically becoming the data shifted in by the next command. A similar approach was used in Listing 4.4 (Feb '10), where multiple counters were cascaded to create a custom counter/timer.

A potential disadvantage of this technique is the possibility of making program operation rather cryptic, so it should perhaps be used sparingly, and with appropriate explanation in the form of comments.

Creating user-defined variables

In a complex programming scenario, the software's default allocation of eight auxiliary registers AUX0 to AUX7 (totalling 64 bits) might be insufficient. Fortunately, it is straightforward to create your own user-defined variables, should the need arise.

Currently, allocated general purpose registers are defined toward the start of the appropriate header file, with memory locations 6D–7C (hexadecimal) being unallocated, as of Version 1.1.0. Simply add any required variable definitions in this section of the appropriate header file, being careful

```
                          ; Unused Ram locations 6DH – 74H

TEMP0     EQU     H'75'   ; Block of eight user defined variables (start)
TEMP1     EQU     H'76'
TEMP2     EQU     H'77'
TEMP3     EQU     H'78'
TEMP4     EQU     H'79'
TEMP5     EQU     H'7A'
TEMP6     EQU     H'7B'
TEMP7     EQU     H'7C'   ; Block of eight user defined variables (end)

STEMP     EQU     H'7D'   ; Stores Status register value during an Interrupt
                          ; Service Routine (ISR)
WTEMP     EQU     H'7E'   ; Stores W register value during an ISR
LOGIC     EQU     H'7F'
LASTRAM   EQU     H'7F'
```

Listing 6.3. Defining a block of eight user defined variables

```
        include "16F627.PLC"        ; Defines PLC instructions

                                    ; Start of main program

        call    SUB1                ; Call subroutine 1 unconditionally

        goto    loop                ; Go to start of scan loop

                                    ; Put subroutine definitions after main
                                    ; program, but before 'endp' statement.

                                    ; Subroutine 1 (called always)
SUB1    puti    b'00110011', PORTB  ; Display 33H on Port B
        return                      ; Return to main program

        endp                        ; End of PLC program
```

Listing 6.4. Mixing assembly language and ladder logic (Lst6_4.asm)

not to use any previously defined variable names. The example of Listing 6.3 creates an additional eight auxiliary registers called TEMP0–TEMP7, hence increasing the number of available auxiliary relays from 64 to 128.

On a cautionary note, there is no guarantee that these locations will not be allocated by future versions of the software. With this in mind, it is a good idea to place any user-defined variables at the top end of available memory, since locations are generally allocated from low to high.

Mixing assembly language and ladder logic

It is quite permissible to mix assembly language statements and ladder logic in a single source code program, provided that the actions performed are themselves compatible. A simple but useful example would be the use of subroutine 'call' and 'return' instructions, which would allow a more structured approach to program design. Listing 6.4 shows a simple example.

The program may be seen to contain three assembly language statements which are, in order 'call', 'goto' and 'return', plus two ladder logic statements 'puti' and 'endp'. There is also the 'include' assembler directive, plus the 'SUB1' label, which has been placed in the left margin in order to identify the start of the subroutine definition.

Subroutines may be thought of as small self-contained sub-programs, which are called from the main program, optionally returning a result in the W register. Return addresses are stored in a dedicated area of memory called the stack. Supported PIC micros have an eight-level-deep stack, allowing subroutine calls to be 'nested' up to eight levels deep. (However, bear in mind that the PLC software makes use of interrupts, hence using the stack to hold return addresses from interrupt service routines. This means that you should not nest subroutines more than seven levels deep with the PLC software.)

The subroutine is called from the main program, with the subroutine identified by a label which is placed in the left margin next to the first instruction. The return statement causes execution of the main program to resume at the program line immediately following the call statement.

It is necessary to place the subroutine definitions outside of the main scan loop, in order to avoid a software crash due to stack 'underflow' (trying to return from a subroutine which hasn't actually been called in the proper way). This is achieved by placing a 'goto loop' statement after the main program, but before the subroutine definitions. The final program statement must still be the 'endp' macro statement, which contains an additional 'goto loop' statement, plus the required 'END' of program assembler directive.

While this example does demonstrate the possibilities of mixing assembly language and ladder logic, it is structurally rather clumsy. The following section on customisation will answer this potential criticism, beginning by developing a custom extension facility for conditional and unconditional subroutine execution. This will provide us with enhanced structured programming, plus the ability to make 'if…then…else' style decisions.

Adding custom extensions to the software

This section will consider three different customisation scenarios, each of which will add a significant new capability to the software. Topics considered will be:

- Conditional program execution
- Code conversion
- Finite state machine.

(Recall from the introduction that these new features are included with the updated version of the PLC software supplied with this final part of the series.)

Scenario 1 – conditional code execution

In the previous section, we saw just how easy it is to add subroutines to our ladder logic programs. The 'call' and 'return' assembly language statements, when used appropriately, allow the use of subroutines within ladder logic programs. On the downside, we had the added complexity of 'labels' in the left margin, plus the need to add a 'jp loop' statement at the end of the main program, and before the subroutine definitions.

The addition of two new macros will cure these issues, while also offering the capability to call a subroutine either unconditionally, or only if a test condition is true. These new macro definitions are shown in Listing 6.5.

At this stage, you may like to refer back to Fig.2.7 and associated text from Part 2, which first introduced the macro text substitution feature of the assembler. The essential point to understand is that custom macros allow us to create our own new commands, which are first translated into assembly language, and then converted to machine code by the assembler.

As its name suggests, the 'subdef' command is used to define a subroutine, which may then be called in the normal way. The macro accepts a single parameter, which is the name of the subroutine. Notice that this argument is automatically placed into the left margin by text substitution, thus eliminating the need to place your own labels. The second feature of the

```
                                ; The 'subdef' macro defines a subroutine
                                ; (which should end with a 'return' statement)
subdef      macro   subdef_arg1
            goto    loop        ; Go to start of scan loop
subdef_arg1                     ; Put label in left margin for call instruction
            endm                ; End of subroutine definition macro

                                ; The 'ccall' macro conditionally calls a
                                ; subroutine, but only if the previous command
                                ; returns a 1 in the LSB of the W register
ccall       macro   ccall_arg1
            andlw   0x01        ; Test least significant bit of W reg.
            btfss   STATUS,Z    ; Skip subroutine if LSB is clear
            call    ccall_arg1  ; Call subroutine
            endm                ; End of macro
```

Listing 6.5. Conditional subroutine macro definitions

```
     include "16F887.PLC"       ; Defines PLC instructions

                                ; Start of main program

     call    SUB1               ; Call subroutine 1 unconditionally

     ld      PORTA, 0
     ccall   SUB2               ; Call subroutine 2 if bit 0 of Port A = 1

     ld_not  PORTA, 0
     ccall   SUB3               ; Call subroutine 3 if bit 0 of Port A = 0

                                ; End of main program

                                ; Put subroutine definitions after main
                                ; program, but before 'endp' statement.

     subdef  SUB1               ; Subroutine 1 is called always
     puti    b'00110011', PORTC ; Display 0x33 on Port C
     return                     ; Return to main program

     subdef  SUB2               ; Subroutine 2 is called if PORTA,0 = 1
     puti    b'00001111', PORTD ; Display 0x0F on Port D
     return                     ; Return to main program

     subdef  SUB3               ; Subroutine 3 is called if PORTA,0 = 0
     puti    b'11110000', PORTD ; Display 0xF0 on Port D
     return                     ; Return to main program

     endp                       ; End of PLC program
```

Listing 6.6. A simple conditional subroutine program (Lst6_6.asm)

macro is a 'jp loop' command, which is automatically placed at the start of each subroutine, hence forcing the subroutine definitions to be outside of the main scan loop. Thus, we have eliminated both of the previously mentioned subroutine issues, by use of an extremely simple macro.

The second 'ccall' macro provides a conditional subroutine call feature, which is an alternative to the unconditional subroutine call discussed previously. The idea is that the result of a previous command, such as a 'ld' or 'ld_not', is tested by the ccall statement, with the subroutine being called, only if the command returns a true result (as indicated by a logic 1 in the least significant bit of the W register).

The example of Listing 6.6 illustrates the use of our newly defined 'ccall' and 'subdef' macros, plus previously considered 'call' and 'return' assembly language commands, to implement conditional and unconditional subroutines.

Notice that the program defines three subroutines, SUB1, SUB2 and SUB3, which are placed after the main program, but before the final 'endp' statement. The main program consists of just three lines, the first being an unconditional call to the first subroutine, followed by conditional calls to subroutines two and three. Notice that the conditional calls are complementary, based on the state of bit 0 of Port A, so only one conditional subroutine call will be made in a single scan loop.

This logical structure is important, as will now be discussed.

Tips for using subroutines with ladder logic

In a typical high level programming language, subroutines are designed to be called many times from the main program, thus offering a reusable library of pre-tested code. The purpose is slightly different in our ladder logic implementation, with subroutines offering a more structured program layout, plus the ability to conditionally execute a block of code if a tested condition is true.

In general, some care is needed when designing subroutine-based ladder logic programs, to ensure that individual register bits, such as inputs and outputs, are only updated once per scan cycle. For example, if an output is set to 1 at the start of the scan loop and later set to 0, the output will appear to oscillate as the scan cycle repeatedly executes. Thus, any 'complementary' actions contained within subroutines should be called by mutually exclusive test conditions, as found in an if…then…else program structure.

Available subroutine related commands are summarised in Table 6.1.

Scenario 2 – code conversion

The 'retlw' assembly language instruction may be used as an alternative to the 'return' statement seen earlier, offering the facility to place a literal value in the W register on returning from a subroutine. This feature commonly allows subroutines to return a result to the calling program, or possibly a success/failure result code. However, with some clever coding, the retlw command may be persuaded to perform code conversion, transforming binary values into a variety of other

Command	Function
`call SUBROUTINE`	Call a named subroutine unconditionally (assembly language statement).
`return`	Return to the main program, at the line following the subroutine call (assembly language statement).
`ccall SUBROUTINE`	Call a named subroutine conditionally, if the previous command returns a true result (in least significant bit of W register).
`subdef SUBROUTINE`	Define a named subroutine.

Table 6.1. Subroutine-related commands

```
; The 'bin27seg' macro calls the following subroutine which must be placed in
; the first 256 locations of program memory

                                   ; * 7-segment display look up table
                                   ; subroutine
bin27seg_sub1 andlw   0x0f         ; Mask off upper 4 bits of W to prevent table
                                   ; overflow
              addwf   PCL          ; Add W to LSB of program counter and return
                                   ; with look up value in W
              retlw   b'00111111'  ; Display = '0'
              retlw   b'00000110'  ; Display = '1'
              retlw   b'01011011'  ; Display = '2'
              retlw   b'01001111'  ; Display = '3'
              retlw   b'01100110'  ; Display = '4'
              retlw   b'01101101'  ; Display = '5'
              retlw   b'01111101'  ; Display = '6'
              retlw   b'00000111'  ; Display = '7'
              retlw   b'01111111'  ; Display = '8'
              retlw   b'01100111'  ; Display = '9'
              retlw   b'01110111'  ; Display = 'A'
              retlw   b'01111100'  ; Display = 'B'
              retlw   b'00111001'  ; Display = 'C'
              retlw   b'01011110'  ; Display = 'D'
              retlw   b'01111001'  ; Display = 'E'
              retlw   b'01110001'  ; Display = 'F'

; Macro definition for binary to segment display conversion.

bin27seg   macro   bin27seg_arg1, bin27seg_arg2
           movf    bin27seg_arg1, W        ; Put binary value into W
           call    bin27seg_sub1           ; Call lookup subroutine
           movwf   bin27seg_arg2           ; Put result in destination register
           endm                            ; End of Binary to 7-segment
                                           ; display converter macro
```

Listing 6.7. Binary-to-7-segment display subroutine and macro

upper four bits of the binary value to zero, thus preventing a potential table overflow.

One slightly undesirable feature of this technique is that the lookup table subroutine becomes a permanent feature of the assembled program, even if the associated macro is not used. This inevitably leads to a small increase in the minimum size of assembled machine code programs, but this should not be a significant issue, given that up to 8k of program memory is available in supported PIC microcontrollers. It should also be noted that any lookup table subroutines must be placed in the first 256 locations of program memory, in order to prevent memory page errors when the W register is added to the lower byte of the program counter.

Fig.6.1 shows a potential application of this technique to drive a single 7-segment display, with the associated program shown in Listing 6.8.

As can be seen, the resulting binary to 7-segment display program is remarkably simple, from a programming perspective at least, consisting of a single line of code. The real complexity is hidden in the lookup table and associated macro definition.

Clearly, the method used here with 7-segment displays may easily be applied to other code conversion scenarios. With this in mind, a diverse selection of code conversion macros has been developed, covering topics including position measurement (Gray code), stepper motor control, plus binary encoders and decoders, as given in Table 6.2.

representations. This is an extremely powerful technique, with potential applications including:

- 7-segment displays
- Gray code (position measurement)
- Stepper motor control
- Binary encoders and decoders.

The basic idea is to create a subroutine which contains a lookup table consisting of a series of retlw statements, each of which will return a particular value to the calling program. We then place our initial binary value (to be converted) into the W register prior to calling the subroutine. The subroutine begins by adding the value contained in the W register to the program counter register, which causes the PIC micro to jump forwards in program memory by the number of locations specified, hence returning the converted value in the W register.

The example of Listing 6.7 shows a subroutine used to convert a 4-bit binary value to a format capable of driving a directly connected 7-segment display, plus the associated macro definition.

This example creates a new 'bin27seg' (binary to seven segment) macro definition, which in turn calls the 'bin27seg_sub1' subroutine to perform the actual code conversion. Notice the use of bit masking at the start of the subroutine as a data validation check, forcing the

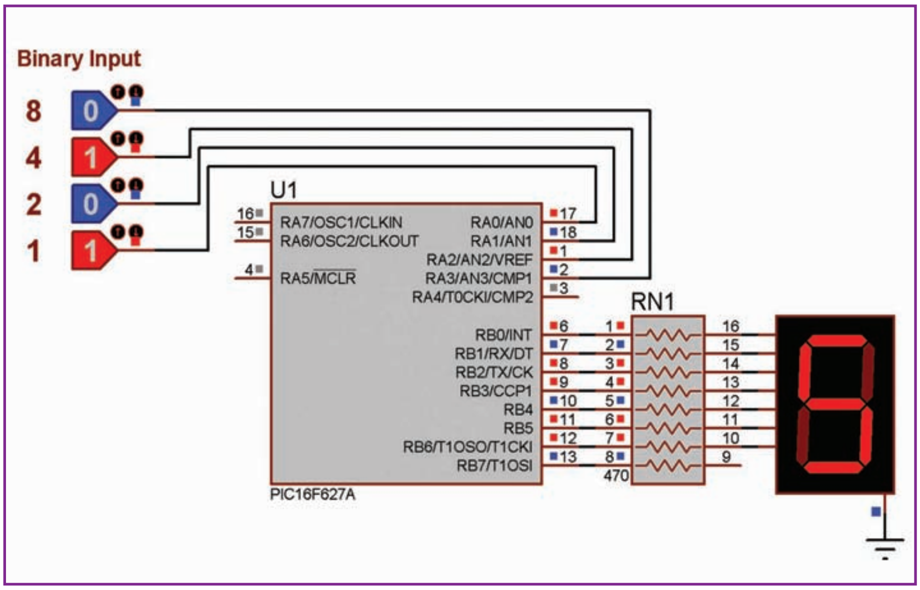


Fig.6.1. Displaying a binary value on a 7-segment display

```
    include "16F627.PLC"   ; Defines PLC instructions

    bin27seg  PORTA, PORTB ; Display binary code from PORTA bits 0-3
                           ; on 7 segment display connected to
                           ; Port B bits 0-6 (bit 7 is unused)

    endp                   ; End of PLC program
```

Listing 6.8. A simple binary-to-7-segment display program (Lst6_8.asm)

Command	Function
bin27seg SRC_REG, DST_REG	Use a 4-bit binary value to drive a directly connected seven segment display.
bin2gray SRC_REG, DST_REG	Convert a 1–4 bit binary value to Gray code.
gray2bin SRC_REG, DST_REG	Convert a 1–4 bit Gray code value to binary.
decode SRC_REG, DST_REG	Use a 1–3 bit binary code to set a single output bit (0–7).
pencode SRC_REG, DST_REG	Produce a priority encoded 3-bit binary value, equivalent to the highest set input bit (0–7).
step SRC_REG, DST_REG	Use a 2-bit binary value to drive a 2-pole stepper motor in full step mode.
hstep SRC_REG, DST_REG	Use a 3-bit binary value to drive a 2-pole stepper motor in half step mode.
swap SRC_REG, DST_REG	Swap nibbles between source and destination registers.

Table 6.2. Available code conversation macros and related commands

```
    include "16F887.PLC"     ; Defines PLC instructions

    puti      0xAB,  AUX0    ; Packed digit display buffer

    bin27seg  AUX0, PORTC    ; Display lower nibble on Port C
    swap      AUX0, AUX1     ; Swap nibbles from display buffer
    bin27seg  AUX1, PORTD    ; Display upper nibble on Port D

    endp                     ; End of PLC program
```

Listing 6.9. Using packed binary values with 7-segment displays (Lst6_9.asm)

Most of these new commands make the same use of lookup tables as the bin27seg command, differing mainly in the number of input bits allowed, and the binary values returned. You can review details of their implementation by viewing the appropriate header file in a text editor. However, note that a couple of these new macros are coded slightly differently: First, the priority encoder (pencode) macro provides the inverse operation to the decoder command, and is implemented as a series of bit tests, rather than as a lookup table. Second, the swap nibbles (swap) macro is provided mainly for use with 7-segment displays, since it allows the upper nibble of a display buffer register to be swapped, prior to outputting to a connected 7-segment display. The latter command allows 'packed' binary values to be used with 7-segment displays, as illustrated by the example program of Listing 6.9.

Multiplexed 7-segment display

The main problem with the program of Listing 6.9 is its inefficient use of output port bits, since it requires two 8-bit output ports, just to drive a pair of 7-segment displays. A multiplexed 7-segment display is much more efficient in its use of output port bits, as illustrated by Fig.6.2.

Unfortunately, increased I/O efficiency comes at the price of increased complexity of the software. As discussed last month, a multiplexed display operates by briefly activating each digit in a rapidly repeating sequence, thus giving the illusion that all digits are simultaneously illuminated. A suitable control program is shown in Listing 6.10.

Don't worry if this seems complex, since the program can be broken down into a number of smaller sub-sections, each of which is relatively simple to understand.

First, registers AUX0 and AUX1 are used as a display buffer, holding the four digits in packed binary form. Bit 0 of Port A acts as a display enable input, causing the output to be

```
                            ; Multiplexed LED Display

     include "16F887.PLC"    ; Defines PLC instructions

                            ; AUX0 + AUX1 hold 4 digits to be displayed
     puti     0x12, AUX0    ; AUX0 = L.H. 2 digits of display
     puti     0x34, AUX1    ; AUX1 = R.H. 2 digits of display

                            ; AUX2 bits 0+1 waveforms are decoded to produce
                            ; digit scan pulses (see also 'SCANROW' subroutine)
     ld       OSCH, 4       ; Read 8 ms waveform
     out      AUX2, 0       ; Send to bit 0 of register AUX2
     ld       OSCH, 5       ; Read 16 ms waveform
     out      AUX2, 1       ; Send to bit 1 of register AUX2

                            ; Conditional subroutine calls
     ld       PORTA, 0
     ccall    SCANROW       ; Scan rows if bit 0 of Port A = 1

     ld_not   PORTA, 0
     ccall    BLANKED       ; Disable row scan if bit 0 of Port A = 0

     ld       PORTD, 0
     ccall    DIGIT1        ; Display digit 1 if enabled

     ld       PORTD, 1
     ccall    DIGIT2        ; Display digit 2 if enabled

     ld       PORTD, 2
     ccall    DIGIT3        ; Display digit 3 if enabled

     ld       PORTD, 3
     ccall    DIGIT4        ; Display digit 4 if enabled

                            ; Subroutine definitions
     subdef   SCANROW
     decode   AUX2, PORTD   ; Send digit enable pulses to Port D
     return

     subdef   BLANKED       ; Turn off display driver transistors
     puti     0x00, PORTD   ; Blank 7 segment display
     return

     subdef   DIGIT1        ; Display digit 1 subroutine
     swap     AUX0,   AUX3  ; Swap nibbles of AUX0 into AUX3
     bin27seg AUX3,   PORTC ; Send to 7 segment display
     return                 ; Return from subroutine

     subdef   DIGIT2        ; Display digit 2 subroutine
     bin27seg AUX0,   PORTC ; Send to 7 segment display
     return                 ; Return from subroutine

     subdef   DIGIT3        ; Display digit 3 subroutine
     swap     AUX1,   AUX3  ; Swap nibbles of AUX1 into AUX3
     bin27seg AUX3,   PORTC ; Send to 7 segment display
     return                 ; Return from subroutine

     subdef   DIGIT4        ; Display digit 4 subroutine
     bin27seg AUX1,   PORTC ; Send to 7 segment display
     return                 ; Return from subroutine

     endp                   ; End of PLC program
```

Listing 6.10. A multiplexed 7-segment display driver program with blanking control

blanked when it is low, or enabled when high.

The next section of the program copies two of the higher order oscillator bits to register AUX2, which will be used to enable the four display digits in a repeating sequence. These oscillator bits produce a two-bit binary count (00, 01, 10, 11, 00, ...) which repeats more than 50 times per second. This count is 'decoded' by the SCANROW subroutine, to enable each of the four display driver transistors, one after another, but note that the SCANROW subroutine is only called if the display is enabled – as controlled by bit 0 of Port A. When the enable input is zero, then a display blanking subroutine is called instead, which turns off the four transistors (Fig.6.2), thus disabling the display.

During normal operation, the 'decode' macro within the SCANROW subroutine enables each transistor in turn by sending the repeating sequence 0001, 0010, 0100, 1000, 0001 … to Port D. In addition to enabling the display driver transistors, the output bits of Port D are also used to conditionally call a further four subroutines (DIGIT1, DIGIT2, DIGIT3 and DIGIT4), which ensures that the correct binary digit is output to Port C. (Notice also that the display driver subroutines make use of the 'bin27seg' and 'swap' macros considered earlier.)

Controlling stepper motors

Two new macros have been provided to control two-pole stepper motors, in either full-step or half -step mode. The 'step' command takes a two-bit binary input, using it to output the sequence 0011, 0110, 1100, 1001. Similarly, the 'hstep' macro uses a three-bit input code to generate the sequence 0001, 0011, 0010, 0110, 0100, 1100, 1001. As its name suggests, half-step mode uses intermediate states, causing the motor to move in smaller angular increments.

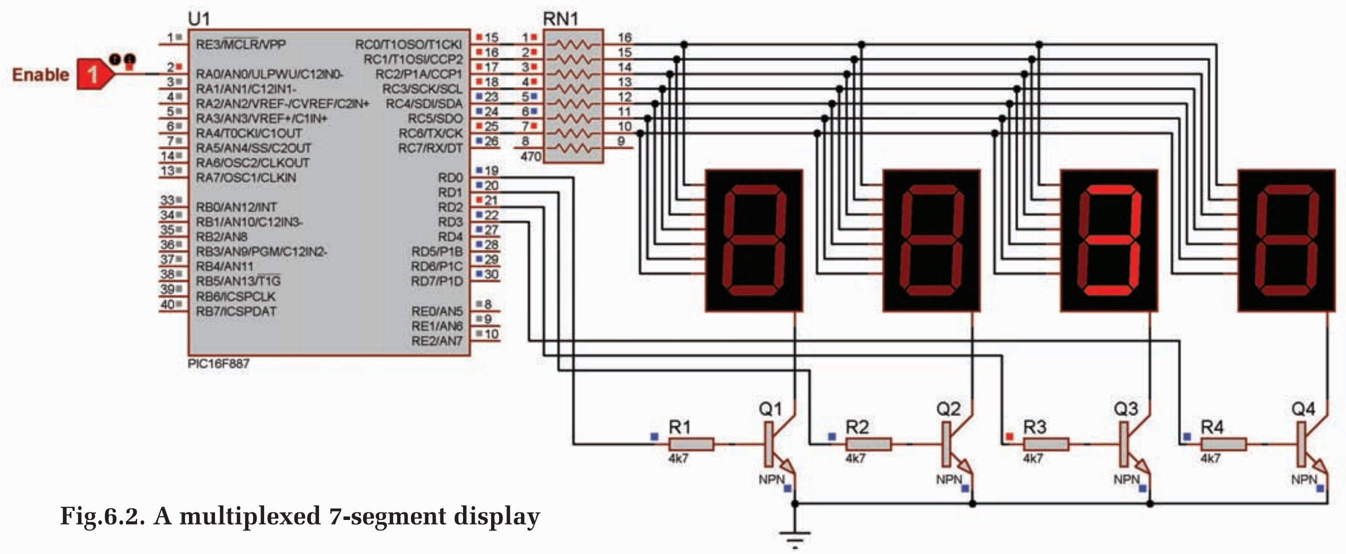


Fig.6.2. A multiplexed 7-segment display

```
include "16F627.PLC"     ; Defines PLC instructions

swap OSCL, AUX0          ; Swap nibbles from OSCL to AUX0
step AUX0, PORTB         ; Send step sequence to bits 0-3 of Port B

endp                     ; Marks end of PLC program
```

Listing 6.11. Basic control of a stepper motor (Lst6_11.asm)

```
include "16F627.PLC"     ; Defines PLC instructions

ld      PORTA, 0         ; Read Port A bit 0 (Count down input)
or      PORTA,1          ; OR with Port A bit 1 (Count up input)
and     OSCL,1           ; Clock input to up/down counter
ctr_ud  0, d'7', PORTA, 1, PORTA, 2
                         ; Up/down counter 0, final value = 7
                         ; Direction = Port A bit 1
                         ; Reset = Port A bit 2
                         ; Up/down counter working register = CUD0

hstep CUD0, PORTB        ; Send half step sequence to bits 0-3 of Port B

endp                     ; Marks end of PLC program
```

Listing 6.12. Bi-directional control of a stepper motor (Lst6_12.asm)

A simple full-step program is shown in Listing 6.11.

The first line places the lowest frequency half of oscillator register OSCL into register AUX0, prior to using this value to drive the stepper motor. (It is also possible to use register OSCL directly to drive the stepper motor, but the speed of operation is then considerably faster.)

A more sophisticated control program is shown in Listing 6.12, with the output of an up/down counter used to provide forward and reverse control, combined with position control based on the running count value.

Hardware connections to inputs and outputs are shown in Fig.6.3.

(Users of Proteus VSM may wish to add a Watch window variable for register CUD0 (address 0x5C), which will allow the desired position of the stepper motor to be observed in real time.)

Digital position measurement (Gray code)

The example of Listing 6.12 illustrated the possibility of open loop position control of a stepper motor. However, stepper motors can easily slip due to their low output torque, so the desired position and the actual position are not always the same thing. The only way to really be sure of the actual shaft position is to measure it, and Gray code is ideally suited to this purpose.

Fig.6.4 shows a 3-bit Gray-coded disc, which may be used to measure rotary shaft position, when combined with suitable opto-coupler hardware.

Gray code uses a special binary counting sequence, such that only one bit changes at any time as the disc rotates. This property eliminates the potential for unwanted intermediate states as the disc rotates.

The latest version of the PLC software provides two new commands related to Gray code. The 'bin2gray' command generates a Gray code value based on a binary input, while the corresponding 'gray2bin' routine generates a binary code based on a Gray-coded input. It is this latter command which is used to measure the position of an output shaft, as illustrated by the example of Listing 6.13.

In this case, a four-bit Gray code on Port A is converted to binary, before being output as a binary value on Port B. Bit masking techniques may optionally be used to reduce the number of input bits, if required.

Scenario 3 – finite state machine

You may recall from Part 5, last month, that a simple sequencer was used to generate one-off or repeating output sequences. This feature was seen to be ideal for generation of timed output sequences, such as those

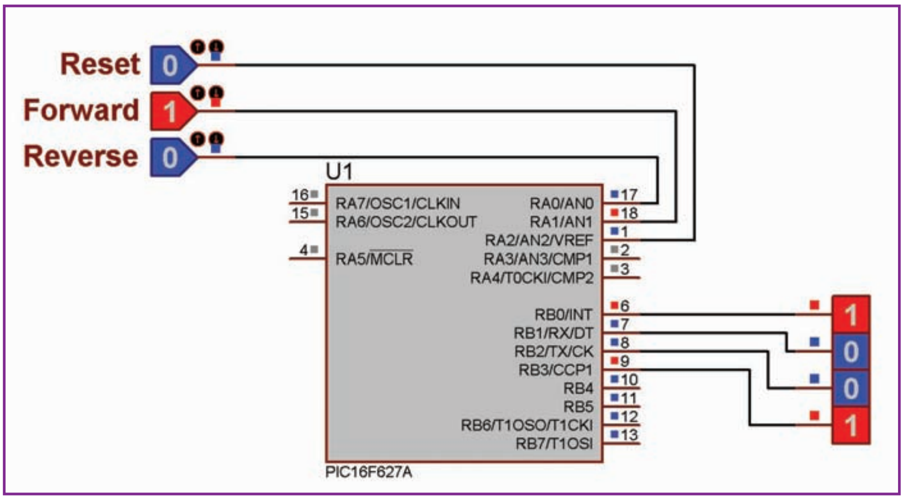


Fig.6.3. Using an up/down counter to control the position of a stepper motor

```
    include "16F627.PLC"          ; Defines PLC instructions

    gray2bin PORTA, PORTB         ; Read a 4-bit Gray coded disc connected to
                                  ; Port A, outputting the position to Port B

    endp                          ; Marks end of PLC program
```

Listing 6.13. Measuring shaft position with a Gray coded disc (Lst6_13.asm)

generated by electronic toys, displays, or even simple traffic lights.

However, the sequencer method is less suited to control-oriented systems, where the exact timing may be impossible to predict in advance, or where progression from one output state to the next is based on the occurrence of an event, which is not necessarily a simple time delay. In this case, a finite state machine may be the best choice, as will be illustrated here.

As its name suggests, a finite state machine is based on the concept of stepping from one 'state' to another, with each transition being triggered by an 'event', which may, for example, be a simple time delay, or an externally generated signal.

Finite state machines are commonly designed in graphical or tabular form, by using either state diagrams, or state tables respectively. As an example, a state table for a simple traffic light sequence is shown in Table 6.3.

As you might have guessed, we can easily add such a capability by creating a new 'state' macro, as illustrated by Listing 6.14.

The macro accepts four parameters which are – just to make it easy – taken directly from our state table. These are the current state number, the next state number, the transition condition, and finally the action to be performed. The transition condition is typically either an input bit, such as PORTA, 0 (which must be set to 1 to cause a transition to the next state), or a timer status bit, which will become set on completion of an associated time delay. In order to keep the program reasonably structured, the final parameter is given as a subroutine name, which is called when the state is active.

The value of the current state is available from the STATE register, which is specified in upper case, to distinguish it from the 'state' macro name (lower case). The system initially powers up in state 0, so an automatic transition is typically made from the power-up state to the first actual step in the sequence.

The actual coding of our traffic light finite state machine is shown in Listing 6.15, this time written for the 16F88 microcontroller.

The program is logically divided into three sections, with the first being the state table

Present State	Next State	Transition Event	Output
0	1	Automatic (power up state)	All outputs off
1	2	2 second delay	Red
2	3	1 second delay	Red + Amber
3	4	10 second delay	Green
4	1	1 second delay	Amber

Table 6.3. A state table representing a simple traffic light sequence

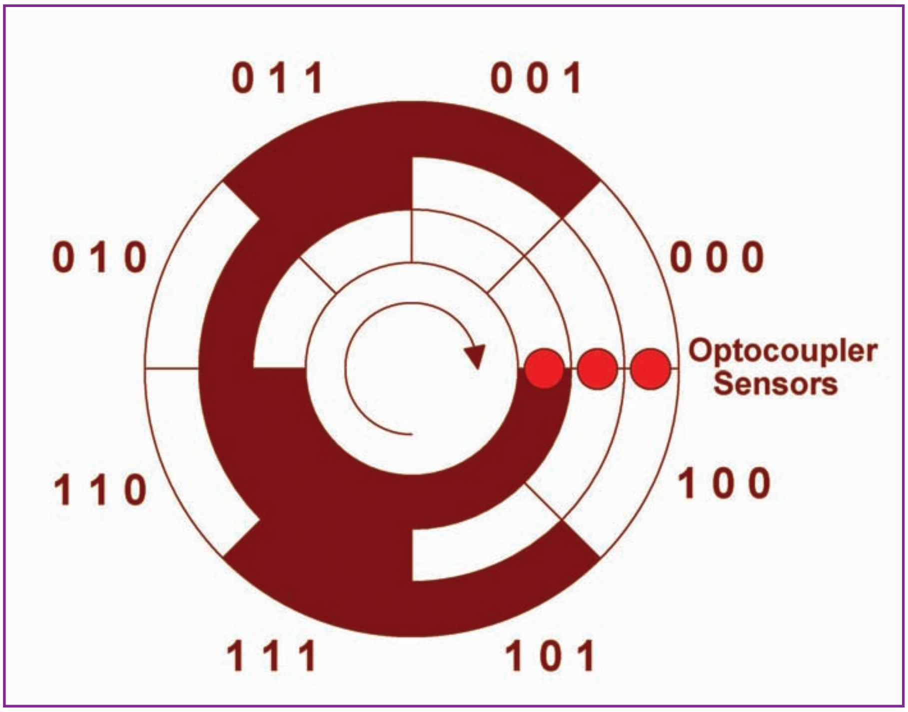


Fig.6.4. Using a Gray-coded disc to measure rotary position

```
state      macro   state_arg1, state_arg2, state_arg3, state_arg4, state_arg5
           movlw   state_arg1              ; Move state number to W
           xorwf   STATE, W                ; XOR with current state (zero result
                                           ; if they are equal)
           btfss   STATUS, Z               ; Check if state_arg1 = current state
           goto    st#v(state_arg1)        ; No, so goto end
           call    state_arg5              ; Yes, so call subroutine
           btfss   state_arg3, state_arg4  ; check if state transition condition
                                           ; is true (1)
           goto    st#v(state_arg1)        ; No so goto end
           movlw   state_arg2              ; Copy next state to STATE register
           movwf   STATE
st#v(state_arg1)
           endm                            ; End of Finite state machine macro
```

Listing 6.14. The custom 'state' macro used by the finite state machine

```
                              ; Traffic Lights - Finite State Machine

   include "16F88_L.PLC"      ; Defines PLC instructions

                              ; First section - Define state sequence

   state 0, 1, LOGIC, 1, ZERO ; Automatic transition from state 0-1
                              ; after power-up

   state 1, 2, TIML, 0, ONE   ; Red
   state 2, 3, TIML, 1, TWO   ; Red + Amber
   state 3, 4, TIML, 2, THREE ; Green
   state 4, 1, TIML, 3, FOUR  ; Amber (then back to Red)

                              ; Second Section - State transitions

   eqi   STATE, 1             ; 2 second timeout state 1-2
   timl  0, 2

   eqi   STATE, 2             ; 1 second timeout state 2-3
   timl  1, 1

   eqi   STATE, 3             ; 10 second timeout state 3-4
   timl  2, d'10'

   eqi   STATE, 4             ; 1 second timeout state 4-1
   timl  3, 1

                              ; Third section - Actions performed

   subdef ZERO                ; All lights off after power up
   puti  b'00000000', PORTB
   return

   subdef ONE                 ; Display Red
   puti  b'00000001', PORTB
   return

   subdef TWO                 ; Display Red + Amber
   puti  b'00000011', PORTB
   return

   subdef THREE               ; Display Green
   puti  b'00000100', PORTB
   return

   subdef FOUR                ; Display Amber
   puti  b'00000010', PORTB
   return

   endp                       ; End of PLC program
```

Listing 6.15. A simple traffic light finite state machine (Lst6_15.asm)

itself. Notice that a LOGIC, 1 value causes an automatic transition from state 0 to state 1, with time delay status bits causing all subsequent state transitions.

The second section uses 'eqi' comparison operators to enable each timer once the STATE register is equal to the tested value. The timer output bit becomes set on completion of the active time delay, causing a transition to the next state, at which point the next timer is enabled, and the previous timer is cleared.

The third and final section contains the subroutine definitions, which in this case output the traffic light values to Port B.

And finally...

The main aims of this series have been to make microcontroller programming accessible to the widest possible audience, and to make it a rewarding experience in the process. I hope I have encouraged you to experiment and to learn more about microelectronics.

The ladder logic software used in the series has been placed into the public domain by the author, so you are free to use it as you see fit, and to extend it to suit new applications. Although it has been carefully tested, like any complex program, you should be aware that the software may contain undetected faults. With this in mind, you should always test your programs carefully, and make sure they perform as required!

I trust that you have enjoyed working along with this series as much as I have in writing it, and I also hope to contribute further articles and construction projects to *EPE* in the future. ***EPE***

Driving LEDs and a Take Note Message

Driving LEDs

THERE have been a couple of threads on the *Chat Zone* in the last few weeks concerning LED driving. Most recently, frequent contributor ***kolbep*** posted the following request to check his LED driver design.

I am busy working on a project where I will need to run five × LEDs at maximum brightness off each PORTA pin. I just wanted to check something before I destroy my last PIC. My plan is to go from say RA0 into pin1 of the ULN2003, then take the output (Pin16) of the ULN2003 to five LEDs in parallel. I just want to know:

1) *If I need any coupling resistors between the PIC and a Darlington array*
2) *How to work out (with LEDs in parallel) what ballast resistor I need. (I know the formula for a single LED is: $R_{ballast} = (V_{sup} - V_{drop\text{-}LED})/I_{LED}$), but I need to know how to adapt for five parallel LEDs (Say all at 5V supply, 2V drop, 20mA)*
3) *Also, anything I may be overlooking.*

Each of the LED groups will all be the same colour and hence current and volt drop.

Alexr quickly replied, pointing out that 'running LEDs in parallel from a single dropping resistor is not a good idea'. We will return to consider this in more detail after a quick look at the ULN2003.

The ULN2003A datasheet provides the answer to kolbep's first point. The datasheet says 'The ULN2003A and ULQ2003A have a 2.7kΩ series base resistor for each Darlington pair for operation directly with TTL or 5V CMOS devices'. This should mean that this IC is compatible with a 5V PIC. The chip pinout is shown in Fig.1.

An overview schematic representing the seven Darlington pairs as NOT gates is shown in Fig.2. The diodes connected to the common point (pin 9) can be used as protection diodes when switching inductive loads. The common ground connection (E, pin 8) is not shown in Fig.2. The schematic of an individual switch is shown in Fig.3; this shows the 2.7kΩ 'coupling resistor' in the base circuit.

Data search

When designing and using semiconductors, particularly integrated circuits, it is always a good idea to look at the datasheet. Before the advent of the internet, this could be difficult because you had to purchase datasheet books, but now they are readily available as PDF downloads. The datasheet for the ULN2003A is available from the Texas Instruments website (**http://focus.ti.com/docs/prod/folders/print/uln2003a.html**).

If you use a search engine to look for the datasheet you will often find copies on websites specialising in supplying datasheets. These can be useful for obsolete parts, but for current devices it is best to go the website of a semiconductor manufacturer that currently makes or supplies the part. This will ensure that you get an up-to-date revision of the datasheet. Another good place to look for current datasheets is on the websites of major component suppliers (such as Farnell, RS and Digi-key).

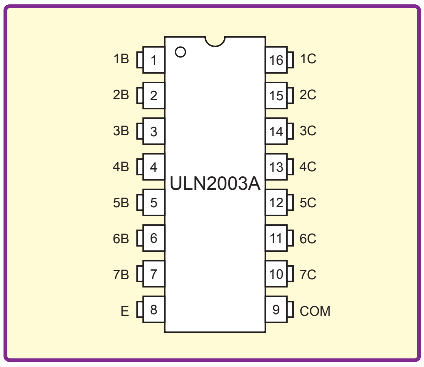


Fig.1. Pinout details for the ULN2003A Darlington array IC

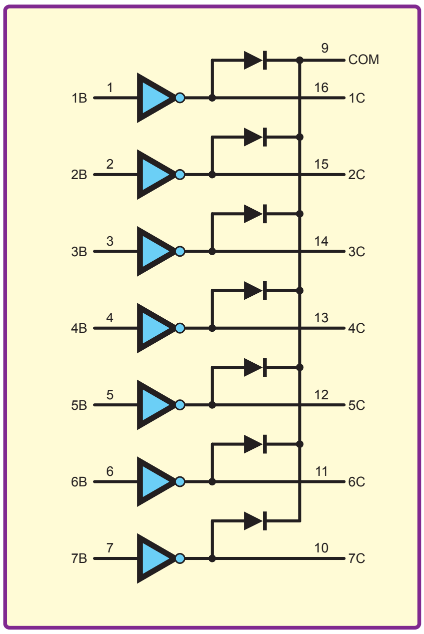


Fig.2. (above). The logic schematic for the ULN2003A Darlington array

Current needs

Returning to kolbep's first point, it is the current through an LED, not the voltage, which sets the brightness; this is the underlying reason why using a single ballast resistor for multiple LEDs is not a good idea.

Two individual LEDs of exactly the same type will produce the same illumination with the same forward current (I_F), but may have different forward voltage drops (V_F) at this current. The variation in voltage drop between individual devices of the same type and colour may be in the range 0.1V to 0.3V for typical LEDs. This is a key fact that needs to be considered when designing LED drive circuits. This is illustrated in Fig.4, which shows possible forward characteristics for two LEDs of the same type.

Fig.5 shows two LEDs driven in parallel using a single current-limiting resistor. Given that each of kolbep's LEDs requires 20mA, we would need 100mA for a similar parallel arrangement of five LEDs. If the forward voltage drop is 2V (from kolbep's data) then the resistor needs to drop 3V at 100mA, so its value should be 30Ω (3V/0.1A) and it would dissipate 300mW (3V×0.1A).

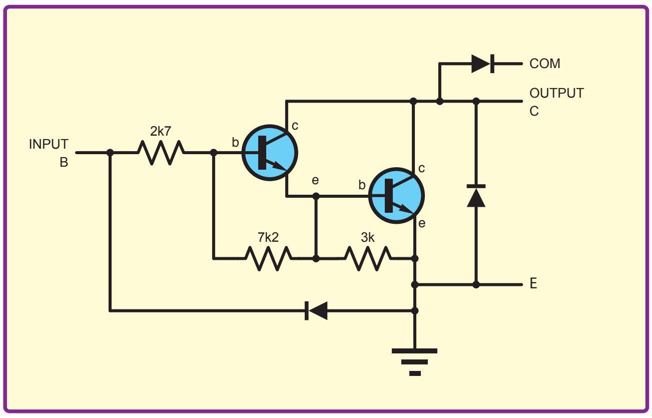


Fig.3. Individual Darlington switch circuit for each section of a ULN2003A IC

Although we have assumed that each LED takes 20mA, in practice they will not share the current flowing from the resistor equally. This circuit forces the LEDs to have the same forward voltage drop, which means that their forward currents and hence brightness may be different (as can be seen from Fig.4). Thus, as we mentioned above, this is not a good approach to driving these LEDs.

Fig.6 shows two LEDs with separate current-limiting resistors; we can still get problems with variation between individual devices resulting in varying brightness. An example will help explain this. Again, using kolbep's data, assume LED1 has a forward voltage drop of 2V at a forward current of 20mA. If the supply (V_S) is 5V we have R1 = 150Ω, so that R1 drops 3V and we have 2V across LED1. If LED2 is also connected with R2 = 150Ω, but has, say, a forward voltage drop of 2.2V due to variations in individual device characteristics, then the current in LED2 will be 18.7mA. The difference in current may show up as a noticeable difference in brightness. The total dissipation in the two resistors is about 0.11W.

If we use a higher supply voltage the brightness variation problem is reduced. For example, consider a 20V supply. Let's say we have R1 = 900Ω to get 20mA with a 2V drop across LED1 (again using kolbep's specification). Now consider LED2 with a 2.2V drop again, and R2 900Ω. The current in LED2 is 19.8mA, almost the same as LED1, so they are more likely to appear equally bright. This comes at a high price though – the total power dissipation in the two current limiting resistors is about 0.71W in the second example, which is more than six times higher than in the 5V version. The higher-voltage circuit is very inefficient, and may not be very suitable for battery powered operation.

Fig.7 shows five LEDs driven in series. The series connection ensures that the current through all the LEDs is equal, so their brightness will also be equal. A potential difficulty with this circuit is that a relatively high voltage is required to drive the series chain. However, if a suitably high voltage is available, kolbep's choice of the ULN2003 is appropriate, because it is a 'high voltage' switch, rated at 50V.

A compromise

For a large number of LEDs, a compromise between parallel and series connection can reduce the need for a very large supply voltage. This is illustrated by Fig.8, where 15 LEDs are connected in three groups of five in series. For a 2V drop it should be possible to use a series connection of five LEDs from a 12V supply, which may be easier to organise than, say, 36V for a single chain. The voltage used should be sufficient to allow for all the LEDs to have the largest voltage drop indicated by their specification at the required brightness level. In this case, if we assume 2.2V is the worse-case voltage we need at least 11V.

The circuit in Fig.8 may suffer from brightness variation between groups. Hopefully, the variation in voltage drop for individual LEDs would be fairly random and each chain would have more or less the same average drop, in which case the brightness variation would be small.

However, if the LEDs in two groups were from different manufacturing batches (maybe if they were purchased at different

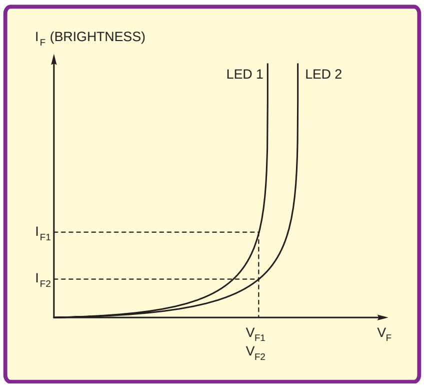


Fig.4. Possible characteristics of two individual LEDs of the same type. With the same forward voltage the LEDs may have different forward currents and hence different brightnesses

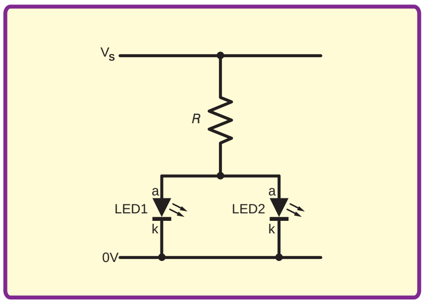


Fig.5. Driving two LEDs in parallel

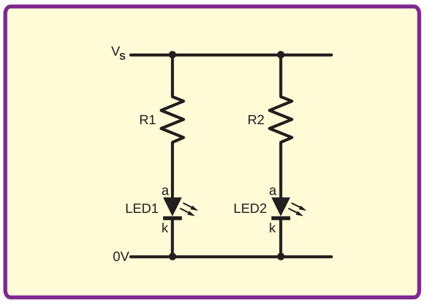


Fig.6. Two LEDs with seperate current-limiting resistors

times), then the brightness variation could be quite large. This problem would be more acute if the supply voltage was close to the minimum required to run the LEDs; since, as we have already seen, a higher supply voltage reduces this problem at the expense of power efficiency.

All of the circuits shown so far have been voltage-driven, but as we mentioned earlier, LED brightness is actually determined by the forward current. It is, therefore, much better to drive LEDs from a constant current source. This is illustrated in Fig.9. The value of I_{LED} is chosen to provide the required brightness (20mA in our examples).

The supply voltage must be high enough to cover all the LED voltage drops, plus the working voltage across the current source circuit. As long as this condition is satisfied, the actual LED voltage drops do not matter. Note that no ballast resistor is required. For a larger number of LEDs, they can be driven in groups from multiple current sources in a similar way to Fig.8, but with a better chance of the groups having even brightness.

It is common in circuits using constant current drive to use a feedback circuit to accurately control the current to the required

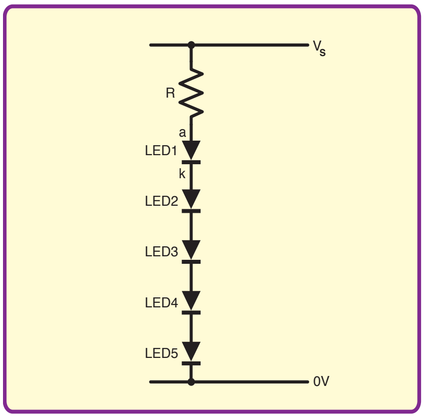


Fig.7. Driving LEDs in series ensures the same forward current, but requires a higher drive voltage

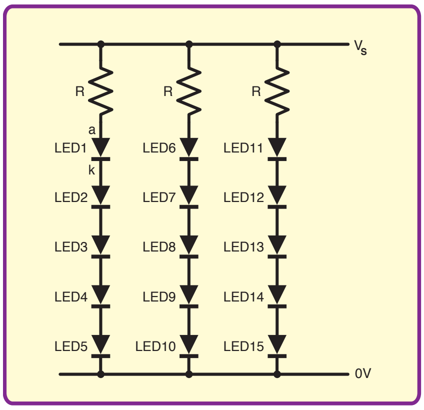


Fig.8. Driving LEDs in series/parallel groups

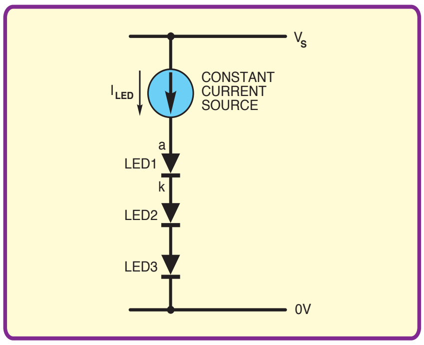


Fig.9. Driving LEDs in series using a constant current source

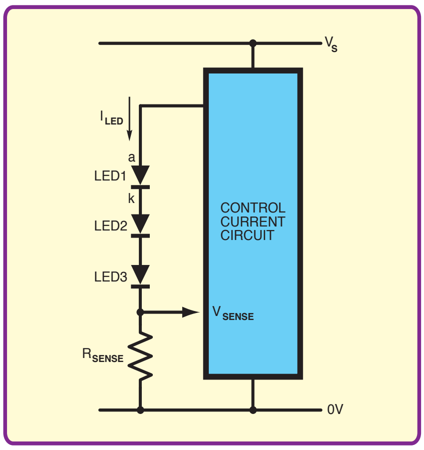


Fig.10. Feedback control for constant current LED drive

value. To measure the actual LED current a sense resistor is inserted in the circuit, as shown in Fig.10. The sense resistor only needs to drop a small voltage to measure the current, therefore a low value can be used (around 10Ω would be typical, much smaller than a typical ballast resistor).

An example of an LED driver chip using this principle is illustrated in Fig.11, it is the MAX8595 from Maxim Integrated Products (**www.maxim-ic.com**). This IC overcomes the problem of finding a voltage high enough to drive the LED chain by providing a switch mode power supply capable of producing up to 38V from a 2.6 to 5.5V supply. This is just one example of the many constant current LED driver chips which are available.

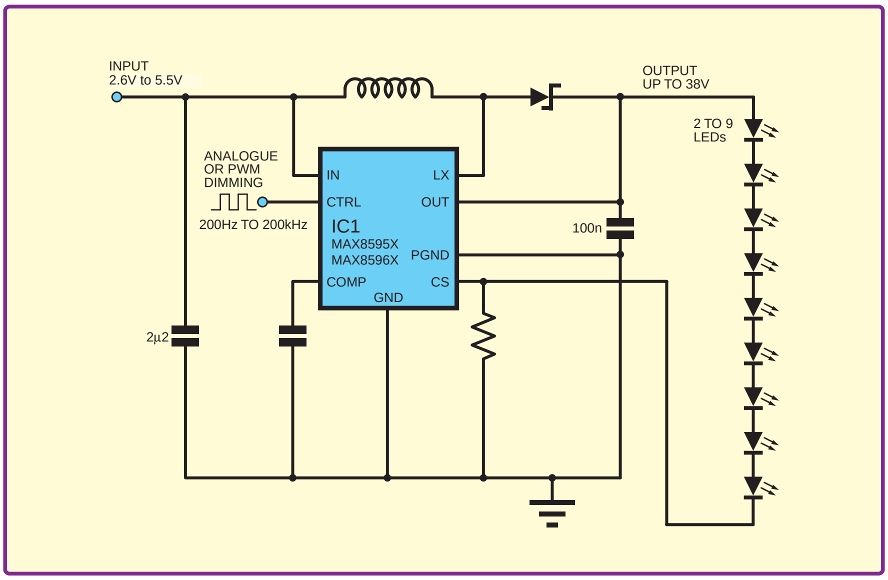


Fig.11. Typical MAX8595X/MAX8596X LED driver circuit.
(circuit from Maxim datasheet – www.maxim-ic.com)

Please Take Note

I have to admit to a major error occurring in *Circuit Surgery* in the Feb '10 issue. We had a letter from ***Alan Pugh*** pointing this out

I am a retired electronic engineer and I occasionally buy a copy of EPE *(when I go into town with my better half and am allowed to wander off) so I bought the Feb '10 issue rather late and the point I am (eventually) going to make; which has probably already been made by many, is that the otherwise excellent article by Ian Bell contains a mistake that may confuse beginners.*

The description of the voltage-current relationship is wrong, in a capacitive circuit, the current leads the voltage by 90º. Later on he says (correctly) that the current peak occurs when the voltage is changing at its fastest rate, ie at the zero crossings. The correct relationship is shown in Fig.8 (not Fig.6) in which the label at the top of the waveform says 'V[vc1]' (not 'V[vl1]' as in Fig.6).

Thank you for producing one of the few interesting electronic magazines left!"

Alan expected many others to have written about this and it is a little worrying that we have not been deluged with letters and emails! However, the error was also spotted by *EPE Chat Zone* forum (**chatzones.co.uk**) contributor ***james***, who reminded us of the useful mnemonic 'CIVIL' – for Capacitors, C I leads V which leads I in L, Inductors.

The root of the problem was the fact that I had accidently swapped the two waveform figures (as Alan points out). These diagrams are obviously the wrong way round if you look carefully at the waveform labels: V[vc1] and I[C1] must apply to the capacitor, and V[vl1] and I[L1] must apply to the inductor, in order to match the simulator schematics in the original Fig.5 and Fig.7 (Fig.12 and Fig.14 here).

It is useful to reflect on how it was possible for me to make such an error despite the knowledge I have possessed for many years. The problem arose because I used the diagrams to write that bit of the description, without engaging my knowledge. This is always a potential risk when using simulation data – one should always check results against one's understanding of the situation; the fundamental principles and mathematics which apply. Failure to do this can mean muddled data or poor simulation models, leading to the wrong conclusions.

The following two paragraphs contain a corrected version of the erroneous text which appeared in the Feb '10 issue (all on page 59). All the relevant diagrams (Fig.12 to Fig.15) are also included here, this time correctly labelled.

For the capacitor (Fig.13), the current waveform is a quarter of a waveform cycle earlier than the voltage, for example, the voltage peaks at 250μs, but the current peaks 50μs earlier at 200μs (a full cycle is 200μs long). Waveform cycles are usually described in angular form (which is independent of the actual time involved), so a quarter cycle is 90°. Here the current has a +90° *phase shift* with respect to the voltage. The current *leads* the voltage by 90°.

For the inductor (Fig.15), the waveforms are similar to the capacitor, except the current phase shift is in the opposite direction; it is –90°. The current *lags* the voltage by 90°.

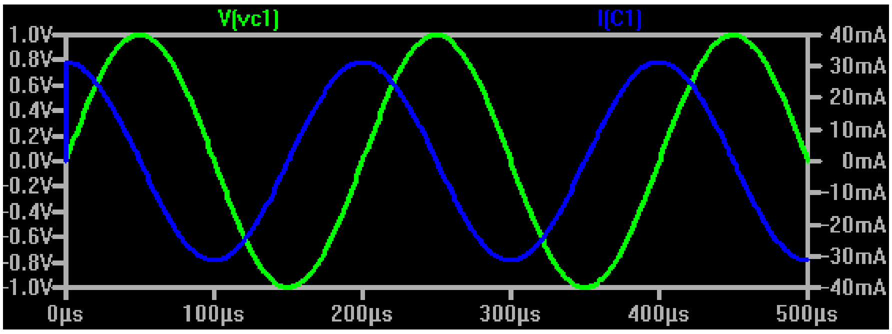


Fig.13. Voltage and current waveforms for capacitor

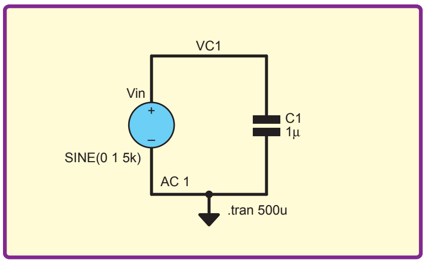


Fig.12. Capacitor circuit

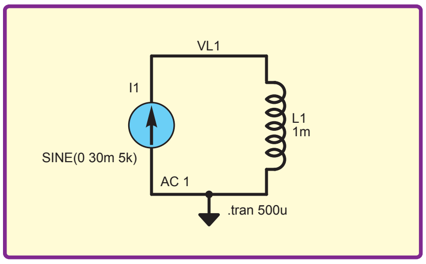


Fig.14. Inductor circuit

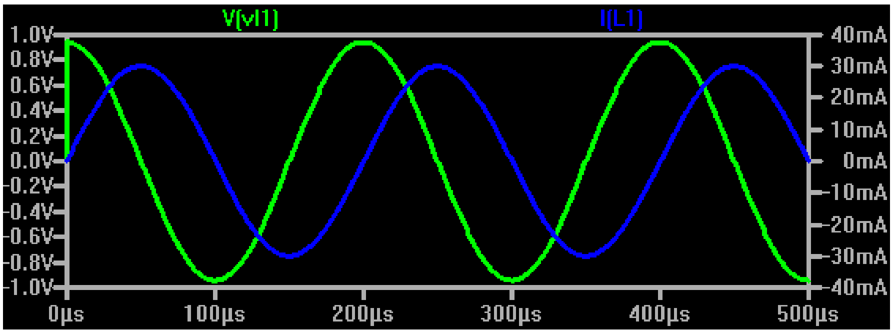


Fig.15. Voltage and current waveforms for inductor

Our periodic column for PIC programming enlightenment

Introducing The Propeller Processor

IN February's issue, Robert Penfold gave an interesting introduction to the Propeller processor demo board from Parallax, and starting this month we thought we would take an in-depth look at the processor, and build a development circuit of our own.

We've been searching for a number of months for a solution to the problem of generating colour video on a small processor, and it was quite by coincidence that Robert's article should appear just days after we discovered the Propeller chip and its on-chip hardware support for generating colour video. The demo board is a nice piece of engineering, with some interesting features, but as Robert pointed out, the number of free I/O pins is limited.

What is it?

So, what exactly is the Propeller Chip? Conceived in the late 1990s by engineers at Parallax Inc, it came to the market in 2006. Frustrated by what they saw as inadequacies in existing microcontroller products, it was originally intended to be a small single-core processor, but through an iterative process of design, test, write software and evaluate, and with falling silicon costs, they ended up at an eight-core controller on a single die.

While we may be becoming used to multiple processing cores on our PCs, courtesy or Intel and AMD, multicore processors are very unusual in the small microcontroller market (in fact we have not seen another – let us know if you have!) This processor is also readily available to the hobbyist, at a very reasonable cost – 5US$ from Digikey, £9 from Farnell. Supplied in both a standard 40-pin DIL and a QFP surface mount format.

Multiple cores

Having eight 'cores' on the chip does not mean that you have eight completely

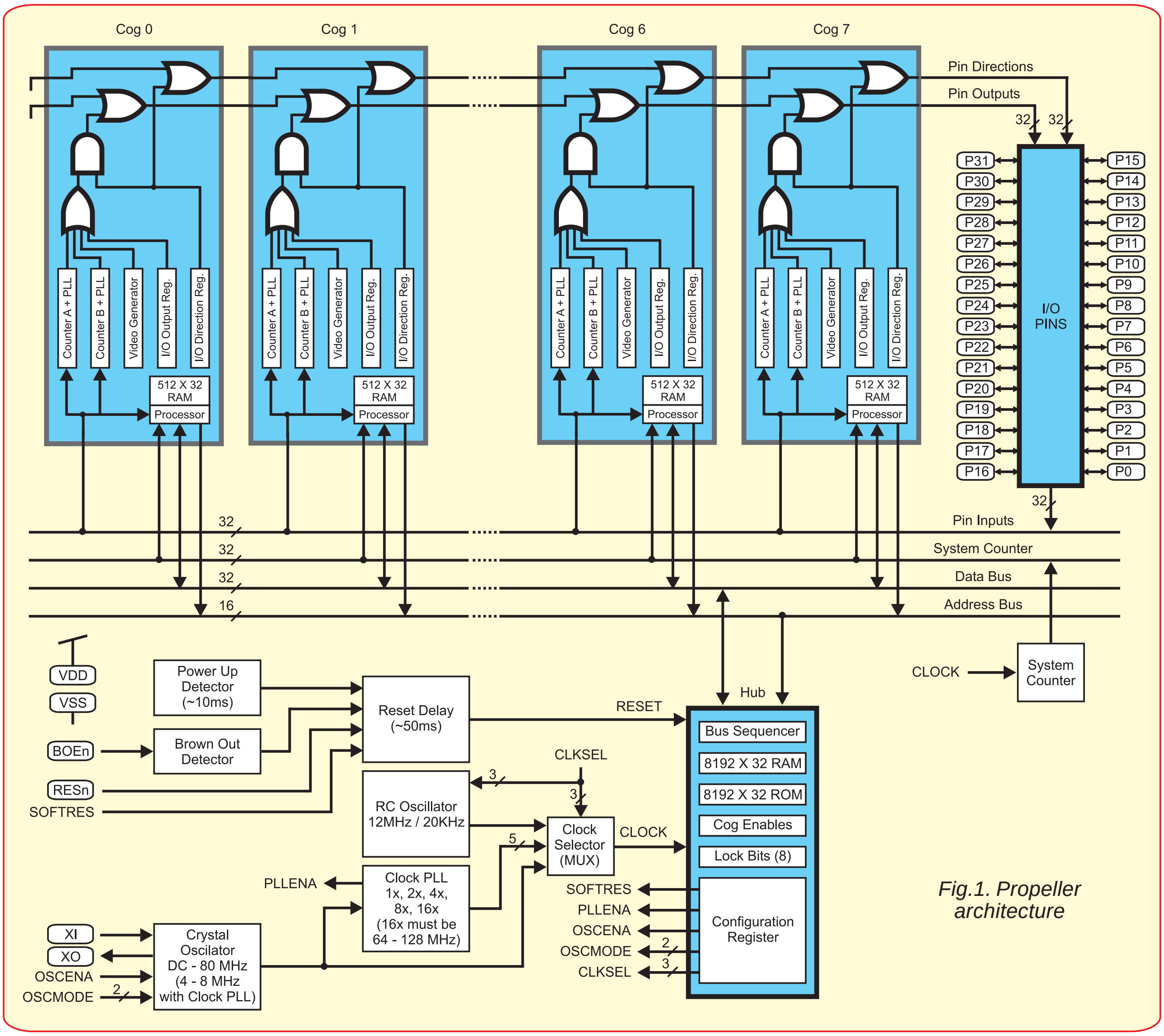


Fig.1. Propeller architecture

independent processors sitting inside a single package. There are eight 32-bit processing units with their own independent program and data area, but sharing access to common peripherals. The setup is shown in Fig.1.

Within each processor is 2KB of RAM that serves as both program and data storage. Each processor also has two counters, video generation hardware and an I/O peripheral to drive the single 32-bit-wide I/O port. As you can see, every processor can drive all 32 I/O pins. It's a flexible arrangement designed so that the individual processors, called 'Cogs', can drive individual pins, or even share control of a single pin if desired.

Interestingly, there are no interrupt capabilities on this device, to which some will give a sigh of relief. The intention is that tasks which would normally require an interrupt, such as an RS232 interface, will be handled by a dedicated Cog. This would poll the receive pin and bit-bash the transmit pin, and write received data into a buffer in common memory, to be picked up and processed by another Cog.

Although 2KB of data and program space sounds small, this is an allocation per Cog – so there is a total of 16KB for the chip as a whole. In addition, there is a single block of 32KB RAM that is accessible by all Cogs. Access to this memory is coordinated through the 'Hub', a synchronisation mechanism that ensures only one Cog can be reading or writing to it at any one time. While all Cogs run in parallel (at up to 20 million instructions per second each, for a maximum performance of 160MIPS!) access to the shared memory has to wait until the Hub allocates a processor a time slot. The Hub 'spins round' at a rate of half the system clock speed, and so a Cog can gain access to the shared memory once every 16 clock cycles.

Every Cog is allocated a slot (even if that Cog is not use) and so the timing of access to shared memory is deterministic, allowing the software developer to optimise their software to account for the delay when waiting for the next time slot. The Hub arrangement is shown in Fig.2

In addition to the 32KB block of shared RAM, the Propeller chip is also equipped with a 32KB block of read only memory (ROM.) The ROM holds a number of useful data tables, including a character set for the video generator and mathematical tables to enable fast log, antilog and trigonometric functions, useful when generating graphical display data.

Spin interpreter

Also held within 8KB of the ROM is a custom language interpreter. Called 'Spin'; it's a very efficient language, not unlike BASIC. A ten-lesson tutorial is presented in the freely available development environment, and there is a wide range of Spin modules available for free on the Parallax website. It's a highly tuned language, even the video generation software examples are written in Spin, which makes writing your own applications much simpler – just copy in the relevant Spin modules to your project and build upon them. Programs can be written in assembler too, but with a very efficient interpreted language built in there is seldom need to work at such a low level. We will be covering Spin next month when we look at the video generation capabilities.

A C compiler is being developed which is also freely available. The aim is to provide a speed improvement over the Spin interpreter and enable existing C programs to be (relatively) easy to port over to the Propeller chip. Whether this will be more efficient in terms of code space is yet to be determined; for us, however, Spin looks like the appropriate route to follow for now.

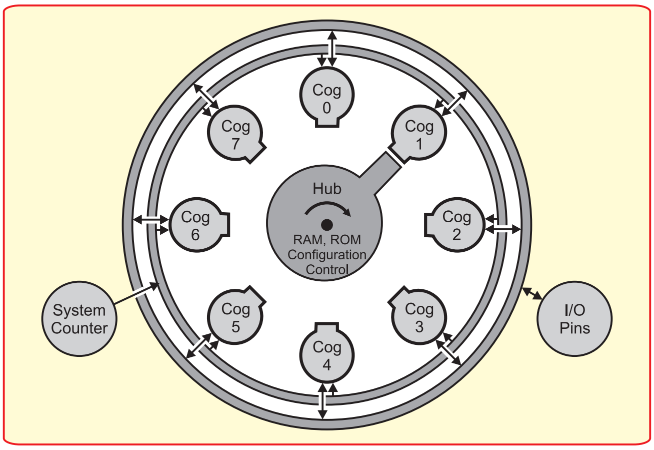


Fig. 2. Hub and Cog interaction

Packages

There is a single version of the Propeller chip at present – the P8X32A, available in three package types: LQFP, a surface mount package with 0.8mm pin spacings, QFN, a surface mount package with no pins at all (almost impossible to hand solder,) and the 40-pin DIP. The DIP package can fit in breadboards or matrix boards, and sockets are cheap, which will make it a favorite with hobbyists. A close inspection of the datasheet suggests that a device with two 32-bit I/O ports may be a future option. And who knows, maybe 16 Cogs? That would be impressive, but is just speculation on our part. The pinout for the DIP package is shown in Fig. 3.

Documentation

Although there isn't a vast amount of information on the Propeller chip available on the web (we PIC enthusiasts have become spoilt over the years,) the available document is clear and well presented. A datasheet, user manual and example demo schematic provide sufficient information to get you started, and there is an online database of free software that can be downloaded and incorporated in your own designs.

A book on the processor has just been released, details of which can be found on the Parallax website. And there is, as you might expect, a very active and friendly user forum.

Development environment

Parallax supply a complete, free, development environment, not unlike MPLAB. It's a lot more straightforward than the Microchip offering, but then this is hardly surprising as they have only a single device to deal with, while MPLAB has hundreds. The Propeller Tool combines editing, compiling and downloading in one simple application. There is no debugging or simulation support, however.

Getting your code into the Propeller is again very different to the more common microcontrollers. There is no non-volatile writable memory on the chip; instead, a built-in bootloader looks to see if a program is being downloaded to it from a serial interface. If not, then it attempts to load an image from an externally attached 32KB or 64KB EEPROM.

The Propeller Tool implements the serial communications interface, and provides a facility to program the attached EEPROM chip through the Propeller. So, from the Propeller tool you can write code and quickly download it to the device. It does mean that any design based on the Propeller must have an EEPROM device too, but such chips are cheap and readily available.

Hardware setup

An external crystal typically in the range of 4MHz to 8MHz is multiplied internally to provide a system clock of up to 80MHz. An internal RC oscillator can also be used, if accurate timings are not required. A standalone system will require a 24LC256 32KB EEPROM for user code storage. The processor runs at between 2.7V and 3.3V and consume only 80mA at full speed, with all Cogs operational.

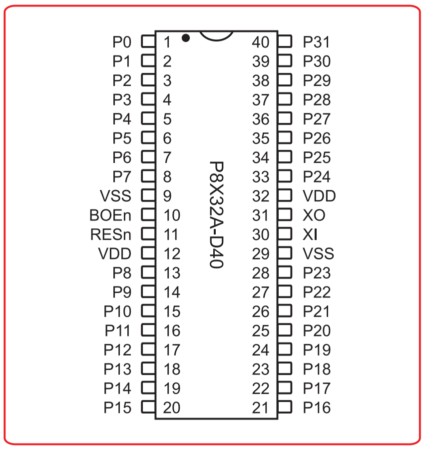


Fig.3. DIP package pinout

Video support

As mentioned earlier, one of the main attractions of this device is its on-chip hardware support for generating video signals. This is a relatively simple circuit that takes care of the most time consuming aspects of bit-bashing composite and SVGA colour signals. This still leaves the processor with a lot to do, but off-loads enough of the processor intensive work to make multiple resolution colour display generation affordable, and it requires very little power consumption.

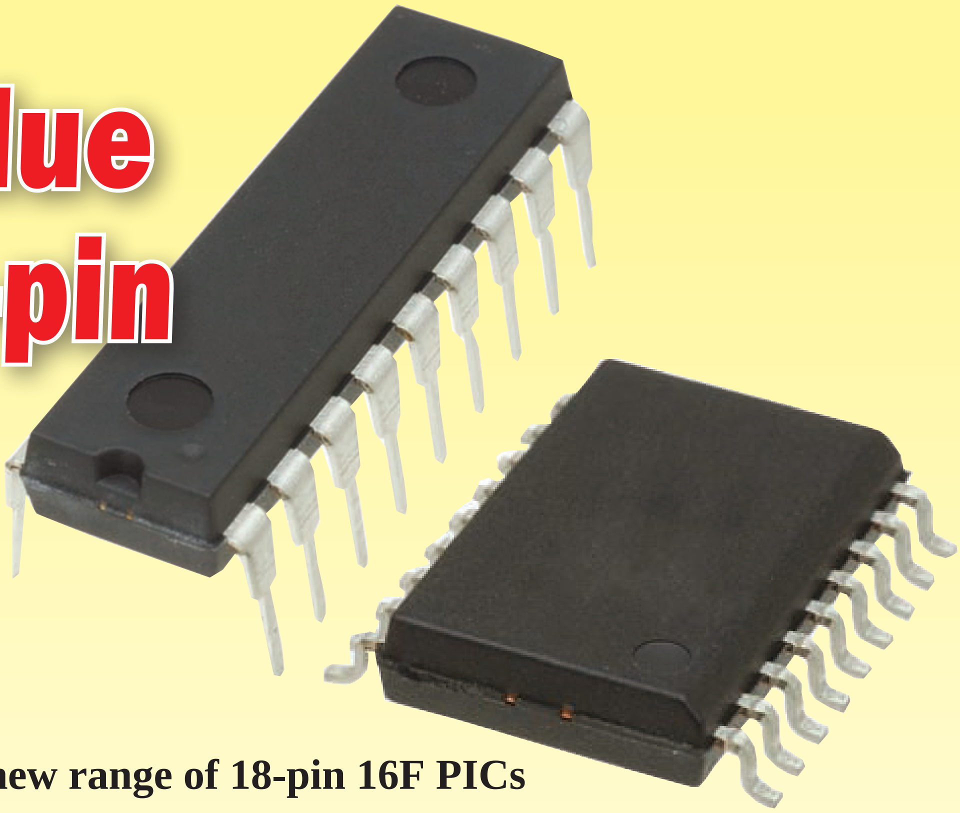
Next month, we will start with the design of a very simple circuit to enable us to work with the video capabilities of the chip, and if successful, we will then look at a practical application circuit.

References

C Compiler: http://forums.parallax.com/forums/default.aspx?f=25&m=388930

Parallax website: http://www.parallax.com/

Best Value Ever 18-pin PICs



by Peter Brunning of Brunning Software

A new range of 18-pin 16F PICs

AROUND the time this magazine goes on sale, the first batch of a new range of 18-pin 16F PICs will be rolling off the production line at Microchip. These new microcontrollers are part of the latest technology eXtremely Low Power PICs. From the name we can deduce they are ideal for battery use, but that is only the beginning of their usefulness.

A few years ago I raved about the PIC16F627A as a replacement for the PIC16F84. Then some months later the PIC16F88 arrived with four times the memory and a 10-bit analogue-to-digital converter. Now, over the last six months I have been looking for and wishing for a suitable 18F PIC with 18 pins, so I could give up 16F PICs altogether.

Future products

'Wow' is the only word for what I discovered on the Microchip website. I looked time and time again on the website for a hint that a new 18F 18-pin PIC was coming. The PIC16F1826 and PIC16F1827 had crept onto the website without getting my attention. They were listed as 'Future Products'. Almost in despair at not finding a suitable 18F PIC I clicked on the PIC16F1827. Although 16F PICs have been given a few new instructions, which take them into the world previously occupied only by 18F PICs, they are exactly what I have been looking for.

The problem with the original 16F PICs is that their programme memory and their RAM is not contiguous, it is arranged in banks. The new 16F XLP PICs still have their memory in banks, but they have new instructions, which allow the banked memory to be handled more easily. The new devices include a relative branch, a dedicated register for the bank number, and two 16-bit pointers, which allow indirect addressing of all the RAM (except 16 bytes) or the programme memory as a contiguous block.

Prices

The other amazing feature is the price. The PIC16F1827 is almost half the price of the PIC16F88, yet has the same amount of memory, same features, and all the advantages of the extended instructions and new features.

Bank selection

Normal 16F PICs have their registers and RAM spread over four banks. The XLP 16F PICs have 16 banks, but because there is now a dedicated register for the bank number, the bank selection instruction takes just one programme memory instead of two. Usually, we do not need to know which bank the registers are in. For example, to set all port B lines as outputs:

```
banksel TRISB
clrf TRISB
```

To set all port B as digital inputs/outputs:

```
banksel ANSELB
clrf ANSELB
```

To set the bank ready to use port B:

```
banksel PORTB
```

Improved features

The new XLP 16F PICs are full of features, many of which already exist in the PIC16F88, but most of these features have been given more flexibility. For example, the Watchdog has a separate prescaler with a much wider range; the internal oscillator can be set from 32kHz to 32MHz; the voltage divider for the comparator has become a digital-to-analogue converter, and so on. It seems every existing feature has been improved and several others have been added.

The purpose of this short article is to bring the XLP 16F PICs into focus. I have been concentrating on the 18 pin PICs because this is where 18F PICs have their only disadvantages. There are also 28-pin and 40-pin PICs in the XLP 16F range, which operate identically to the 18-pin versions. It makes sense for the XLP PICs to take over completely from the existing range of 16F PICs. I can see no disadvantages.

Basic PIC data

PIC type	Pins	Prog Mem	EE	RAM	ADC	USART	Price
PIC16F1826	18	2k × 14	256	256	10bit	yes	£1.33
PIC16F1827	18	4k × 14	256	384	10bit	yes	£1.42
PIC16F627A	18	1k × 14	128	224	no	yes	£1.60
PIC16F88	18	4k × 14	128	384	10bit	yes	£2.72
PIC16F84A	18	1k × 14	64	68	no	no	£3.50

Prices based on UK one-off selling price of 627A using Microchip dollar price as ratio.

By Robert Penfold

INTERFACE

MORE ON USB-TO-SERIAL CONVERSION

The previous *Interface* article covered the basics of the FT232RL and FT245RL USB interface chips. With the aid of free driver software, the FT232RL provides a virtual COM port via a USB port. In effect, it is a USB-to-RS232C-type serial port adapter. With some additional hardware it can be used to provide a true RS232C port. However, in the current context its ability to provide an easy means of interfacing a PC to the serial interface of a suitable microcontroller is probably of more interest.

Dual role

The FT232RL provides a full set of handshake lines, as does the UM232R development module (Fig.1) for this chip. The FTDI development modules have standard DIL pins, and provide an easy option for those who are not prepared to battle with the surface mount encapsulation and 0.65mm pin spacing of the raw chips.

The inclusion of all the handshake lines provides the module with the interesting capability of being able to provide two digital output lines without the need for any additional hardware other than the USB connecting lead. As explained in some previous *Interface* articles, Visual BASIC 2008, including the free Express Edition, can provide direct control of the RTS and DTR handshake output lines.

Of course, the virtual COM port driver software must be installed before the module can be used. My PC automatically installed a suitable driver when the module was connected to a USB port, but if necessary, the driver software and installation instructions can be obtained from the FTDI web site (**http://www.ftdichip.com/**). The driver software actually provides two ways of accessing the chip via a USB port, but it is only the virtual COM port method that will be considered here.

Remember that the software must be set up to use the correct COM port number, even if the PC has only one port of this type. With 'real' COM ports there is a logical method used when the operating system allocates port numbers, but the numbering of virtual ports seems to be purely arbitrary. Once the port is installed in Windows it is a good idea to go to the Windows Control Panel and look at the section that deals with the serial and parallel (COM and LPT) ports.

This should indicate that the port has been installed correctly and that it is working, and it should also provide the port number. In the example of Fig.2 the port has been installed correctly, and it has been set as COM5, even though there is only one other serial port (COM1). The number obtained from the Control Panel is the one applied to the serial port component when writing software for the virtual port.

The Visual BASIC 2008 Help system details the alternative approach of having the application program provide a list of available ports. The user can then select the appropriate port for use by the program. Something of this type is needed if a program will be distributed to users who are using different hardware configurations, and will not all be using the same COM port number.

Listing 2 in the *Interface* article that appeared in the Dec'08 issue of *EPE* demonstrates the basic method used to control the DTR and RTS lines. Even if you are not interested in building projects that utilise this facility of the FT232RL, it does at least provide an easy way of checking that the UM232R module, or another circuit based on the FT232RL, is basically working and communicating with the computer correctly. The pin markings on the UM232R module are a bit confusing, and seem to be the same as those for the UM245R module. The DTR and RTS outputs are at pins 2 and 3 respectively, and will probably be marked 'DB4' and 'DB2'. The DTR and RTS outputs are respectively at pins 2 and 3 of the FT232RL chip.

Fig.2. The numbering of virtual ports seems to be somewhat illogical. In this example, the PC's built-in serial port has been set as COM1, but the virtual port has been set as COM5

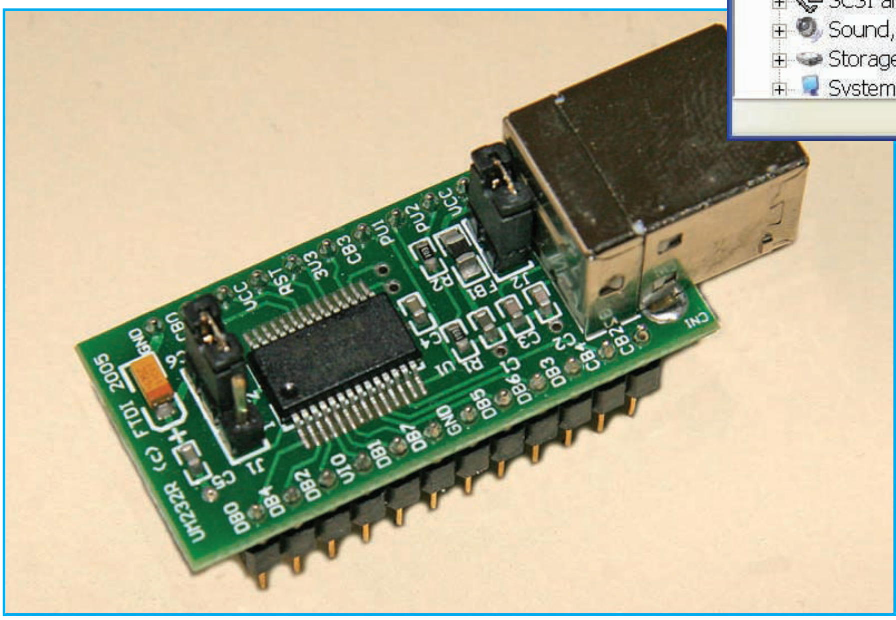


Fig.1. The UM232R module provides a relatively easy way of using the FT232RL USB interface chip. The DTR and RTS outputs of the module can be controlled directly using Visual BASIC 2008 Express Edition

Parallel/serial

As explained in the previous *Interface* article, the FT245RL chip is essentially the same as the FT232RL, but the internal

programming provides a basic serial-to-parallel conversion when it is receiving data, and a conversion in the opposite direction when it is used to transmit data to the computer. In effect, it has a built-in UART (universal asynchronous receiver/transmitter) that avoids the need for any external serial/parallel conversions. This means that it cannot be used with the simple method of interfacing just described, since it does not have the DTR and RTS lines as such. These pins on the FT245RL form part of its 8-bit bidirectional bus.

On the plus side, the FT245RL probably provides the easiest way of interfacing a USB port to multiple input and output lines. This chip seems to be designed primarily for parallel interfacing to a microcontroller, but it is likely that in most real-world applications the FT232RL and serial interfacing would provide a more efficient solution. However, it is not essential to use the FT245RL in conjunction with a microcontroller, and in simple applications it should be possible to use a small amount of conventional control logic circuitry instead.

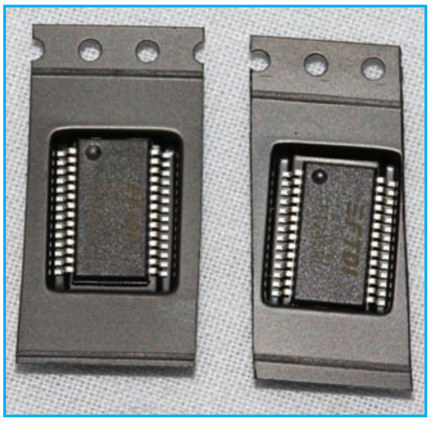


Fig.1. The FT232RL and FT245RL chips are surface-mount types that have 0.65mm pin spacing. The plastic case is fractionally more than 10mm long.

Fig.3 shows the circuit for a basic interface based on the FT245RL. As one would probably expect, it is essentially the same as the circuit for the FT232RL that was featured in the previous *Interface* article. The method of connection to the USB port and the power supply arrangement is exactly the same as in the earlier circuit. The FT245RL can operate with its own supply, or the 'self-powered' mode as it is called in the FT245RL data sheet, but in most cases it is easier to power it from the USB port, as in this example. This is the default mode for the UM245R module incidentally.

The FT232RL normally connects to the main circuit via a two-wire serial link, with the various handshake lines being unnecessary. Matters are inevitably more complicated with the FT245RL due to its 8-bit bidirectional bus, which are D0 to D7 in Fig.3. As with any bidirectional bus, it is essential that the flow of data to and from the bus is regulated correctly. Mistakes here will cause the circuit to malfunction, and there is the risk of damage to the hardware if two sets of outputs are present on the bus at the same time.

The flow of data is controlled with the aid of four control pins on the FT245RL, which must operate together with suitable routines in the microcontroller, or with some conventional control logic. The datasheet for the FT245RL provides timing diagrams for the control and data lines, and the information these diagrams provide is important when trying to get the timing of the control logic absolutely spot on. However, initially it is probably better to consider the function of each control line. Once a grasp of the basic read and write methods has been gained, the timing diagrams are easily understood.

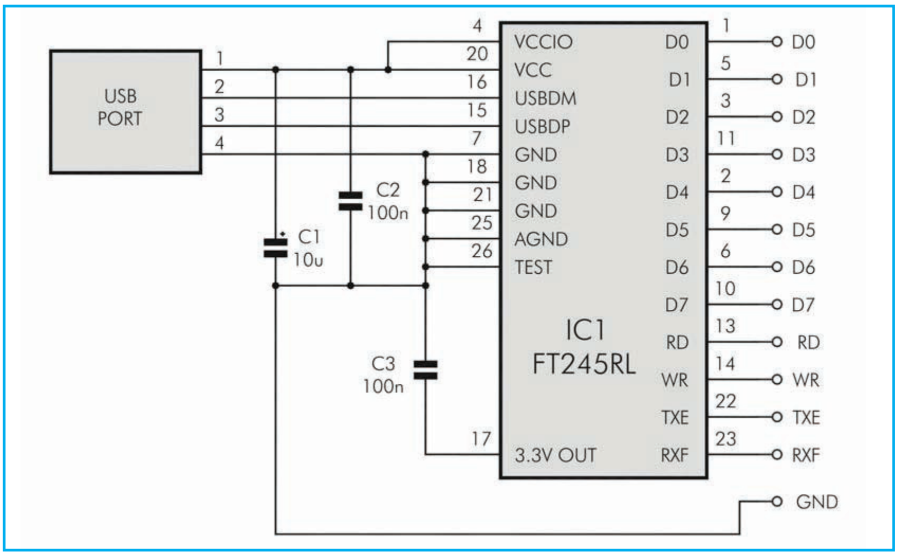


Fig.3. A basic circuit for the FT245RL is essentially the same as the one for the FT232RL that was featured in the previous Interface *article. However, in this case communication with the main circuit is via an 8-bit bidirectional data bus (D0 to D7) and four control lines*

Reading between the lines

Reading from the bus is handled by the RD and RXF pins, which are an input and an output respectively. RXF is normally high (logic 1), but it goes low (logic 0) when a new byte of data becomes available. In order to read the new byte it is necessary to take RD low, read the data lines, and then take RD high again. The data bus is set to the output mode while RD is low, so it is important that this is only done at an appropriate time. It is therefore essential that RD is only strobed low when the RXF output is low. The RXF output is automatically returned to the high state once the strobe pulse on RD has ended.

Sending data is fairly straightforward, but due to the bidirectional nature of the data bus it is not possible to simply send data in an arbitrary fashion. It is important that data is only transmitted when the data bus is not being used to output received data.

The TXE output is used to indicate whether it is safe to transmit data, and it goes high to indicate that a hold-off is required. Therefore, data must only be placed onto the data bus when TXE is low. The outputs driving the data bus must be tri-state types, and they should be in the high impedance state except when actually writing data to the FT245RL.

In order to transmit the data placed on the data bus it is merely necessary to provide a suitable signal to the WR input. The data is loaded into the FT245RL on the high-to-low transition of this pulse. The data will be transmitted whether W/R is normally low and pulsed high, or it is normally held high and is pulsed low. In the former case data is loaded into the chip on the trailing edge of the pulse, whereas it is loaded on the leading edge if W/R is normally high and is pulsed low. The important thing is that the data on the data bus must be valid when the high-to-low transition occurs, and this factor will often dictate the type of strobe pulse used.

Simplification

It is clearly necessary to take due care when designing the transmit/receive control logic, whether it is based on a microcontroller or discrete logic is used. On the other hand, it should be possible to considerably simplify things if the interface will only be used to send data, or to receive it, but not both. For example, when using the interface only for the transmission of data, there should be no risk of the FT245RL itself placing data onto the data bus, since it would not be receiving any bytes of data to output. It might still be a good idea to output data onto the bus via a tri-state buffer controlled from the RXF output, but it is unlikely that this safety measure would ever be brought into action in practice.

Similarly, it should be possible to keep things simple when the FT245RL is only being used to receive data. RXF goes low when a new byte of data is available, and this could be used to trigger a monostable that would provide a brief low pulse to the RD input. The low-to high transition of this pulse would be used to latch the data into an 8-bit data latch.

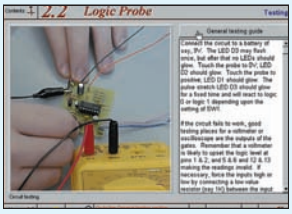
The data should not be latched on the leading edge of this pulse, because this would not give time for the fresh data on the bus to stabilise properly. Where necessary, the output pulses from the monostable could also be used to indicate to the main circuit the availability of new data for processing.

There should be no problems with lost bytes of data when using the FT245RL or the FT232RL, since they both have a 128 byte FIFO (first in – first out) buffer in the transmitter section, and a 256 byte FIFO buffer in the receiver section. Bursts of data at high speed can therefore be stored in the buffers until they can be dealt with. Of course, data can be lost if the flow data into the device is too fast for too long, and a buffer becomes overloaded. Bear in mind that the maximum rate at which data can be transferred is dictated by the virtual serial port, and with a high baud rate this is still much lower than the rates of transfer normally associated with USB ports. This is the price that is paid for the ease with which data can be read from and written to a USB port.

EPE IS PLEASED TO BE ABLE TO OFFER YOU THESE

ELECTRONICS CD-ROMS

ELECTRONICS PROJECTS



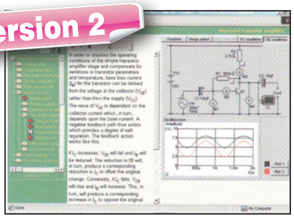
Logic Probe testing

Electronic Projects is split into two main sections: **Building Electronic Projects** contains comprehensive information about the components, tools and techniques used in developing projects from initial concept through to final circuit board production. Extensive use is made of video presentations showing soldering and construction techniques. The second section contains a set of ten projects for students to build, ranging from simple sensor circuits through to power amplifiers. A shareware version of Matrix's CADPACK **schematic capture, circuit simulation** and **p.c.b. design** software is included.

The projects on the CD-ROM are: Logic Probe; Light, Heat and Moisture Sensor; NE555 Timer; Egg Timer; Dice Machine; Bike Alarm; Stereo Mixer; Power Amplifier; Sound Activated Switch; Reaction Tester. Full parts lists, schematics and p.c.b. layouts are included on the CD-ROM.

ELECTRONIC CIRCUITS & COMPONENTS V2.0

Version 2

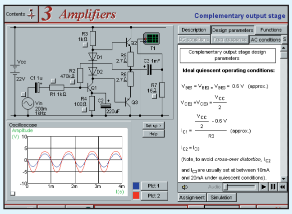


Circuit simulation screen

Electronics Circuits & Components V2.0 provides an introduction to the principles and application of the most common types of electronic components and shows how they are used to form complete circuits. The virtual laboratories, worked examples and pre-designed circuits allow students to learn, experiment and check their understanding. Version 2 has been considerably expanded in almost every area following a review of major syllabuses (GCSE, GNVQ, A level and HNC). It also contains both European and American circuit symbols. Sections include: ***Fundamentals***: units and multiples, electricity, electric circuits, alternating circuits. ***Passive Components***: resistors, capacitors, inductors, transformers. ***Semiconductors***: diodes, transistors, op amps, logic gates. ***Passive Circuits. Active Circuits***. *The Parts Gallery* will help students to recognise common electronic components and their corresponding symbols in circuit diagrams.

Included in the Institutional Versions are multiple choice questions, exam style questions, fault finding virtual laboratories and investigations/worksheets.

ANALOGUE ELECTRONICS



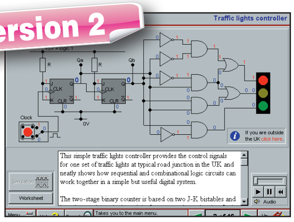
Complimentary output stage

Analogue Electronics is a complete learning resource for this most difficult branch of electronics. The CD-ROM includes a host of virtual laboratories, animations, diagrams, photographs and text as well as a SPICE electronic circuit simulator with over 50 pre-designed circuits.

Sections on the CD-ROM include: ***Fundamentals*** – Analogue Signals (5 sections),Transistors (4 sections), Waveshaping Circuits (6 sections). ***Op Amps*** – 17 sections covering everything from Symbols and Signal Connections to Differentiators. ***Amplifiers*** – Single Stage Amplifiers (8 sections), Multi-stage Amplifiers (3 sections). ***Filters*** – Passive Filters (10 sections), Phase Shifting Networks (4 sections), Active Filters (6 sections). ***Oscillators*** – 6 sections from Positive Feedback to Crystal Oscillators. ***Systems*** – 12 sections from Audio Pre-Amplifiers to 8-Bit ADC plus a gallery showing representative p.c.b. photos.

DIGITAL ELECTRONICS V2.0

Version 2



Virtual laboratory - Traffic Lights

Digital Electronics builds on the knowledge of logic gates covered in *Electronic Circuits & Components* (above), and takes users through the subject of digital electronics up to the operation and architecture of microprocessors. The virtual laboratories allow users to operate many circuits on screen.

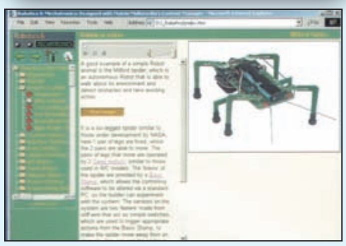
Covers binary and hexadecimal numbering systems, ASCII, basic logic gates, monostable action and circuits, and bistables – including JK and D-type flip-flops. Multiple gate circuits, equivalent logic functions and specialised logic functions. Introduces sequential logic including clocks and clock circuitry, counters, binary coded decimal and shift registers. A/D and D/A converters, traffic light controllers, memories and microprocessors – architecture, bus systems and their arithmetic logic units. Sections on Boolean Logic and Venn diagrams, displays and chip types have been expanded in Version 2 and new sections include shift registers, digital fault finding, programmable logic controllers, and microcontrollers and microprocessors. The Institutional versions now also include several types of assessment for supervisors, including worksheets, multiple choice tests, fault finding exercises and examination questions.

ANALOGUE FILTERS

Filter synthesis

Analogue Filters is a complete course in designing active and passive filters that makes use of highly interactive virtual laboratories and simulations to explain how filters are designed. It is split into five chapters: **Revision** which provides underpinning knowledge required for those who need to design filters. **Filter Basics** which is a course in terminology and filter characterization, important classes of filter, filter order, filter impedance and impedance matching, and effects of different filter types. **Advanced Theory** which covers the use of filter tables, mathematics behind filter design, and an explanation of the design of active filters. **Passive Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev ladder filters. **Active Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev op.amp filters.

ROBOTICS & MECHATRONICS



Case study of the Milford Instruments Spider

Robotics and Mechatronics is designed to enable hobbyists/students with little previous experience of electronics to design and build electromechanical systems. The CD-ROM deals with all aspects of robotics from the control systems used, the transducers available, motors/actuators and the circuits to drive them. Case study material (including the NASA Mars Rover, the Milford Spider and the Furby) is used to show how practical robotic systems are designed. The result is a highly stimulating resource that will make learning, and building robotics and mechatronic systems easier. The Institutional versions have additional worksheets and multiple choice questions.

- Interactive Virtual Laboratories
- Little previous knowledge required
- Mathematics is kept to a minimum and all calculations are explained
- Clear circuit simulations

PRICES

Prices for each of the CD-ROMs above are:

(Order form on third page)

Hobbyist/Student	**£45**	**inc VAT**
Institutional (Schools/HE/FE/Industry)	**£99**	**plus VAT**
Institutional 10 user (Network Licence)	**£249**	**plus VAT**
Site licence	**£499**	**plus VAT**

(UK and EU customers add VAT at 15% to 'plus VAT' prices)

PICmicro TUTORIALS AND PROGRAMMING

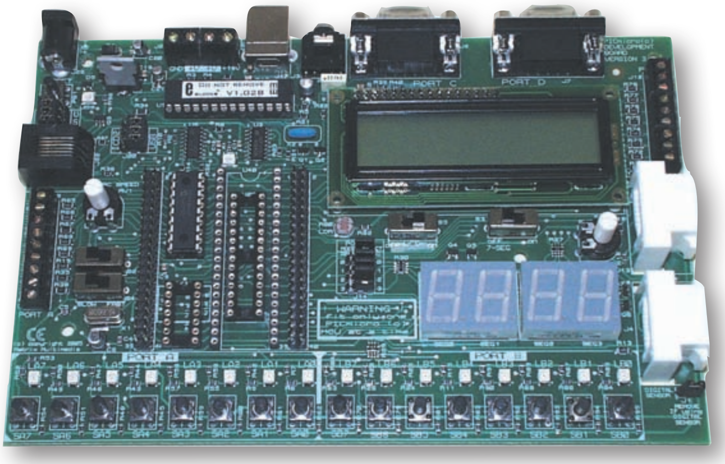
HARDWARE

VERSION 3 PICmicro MCU development board

Suitable for use with the three software packages listed below.

This flexible development board allows students to learn both how to program PICmicro microcontrollers as well as program a range of 8, 18, 28 and 40-pin devices from the 12, 16 and 18 series PICmicro ranges. For experienced programmers all programming software is included in the PPP utility that comes with the development board. For those who want to learn, choose one or all of the packages below to use with the Development Board.

- Makes it easier to develop PICmicro projects
- Supports low cost Flash-programmable PICmicro devices
- Fully featured integrated displays – 16 individual LEDs, quad 7-segment display and alphanumeric LCD display
- Supports PICmicro microcontrollers with A/D converters
- Fully protected expansion bus for project work
- USB programmable
- Can be powered by USB (no power supply required)



£158 including VAT and postage, supplied with USB cable and programming software

SOFTWARE

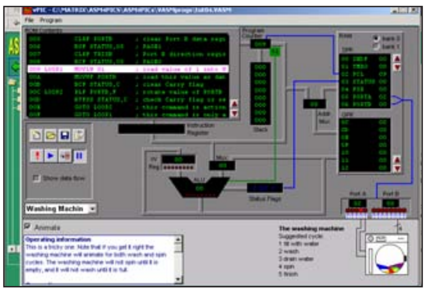
ASSEMBLY FOR PICmicro V3

(Formerly PICtutor)

Assembly for PICmicro microcontrollers V3.0 (previously known as PICtutor) by John Becker contains a complete course in programming the PIC16F84 PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes.

The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro microcontroller, this is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed, which enhances understanding.

● Comprehensive instruction through 45 tutorial sections ● Includes Vlab, a Virtual PICmicro microcontroller: a fully functioning simulator ● Tests, exercises and projects covering a wide range of PICmicro MCU applications ● Includes MPLAB assembler ● Visual representation of a PICmicro showing architecture and functions ● Expert system for code entry helps first time users ● Shows data flow and fetch execute cycle and has challenges (washing machine, lift, crossroads etc.) ● Imports MPASM files.

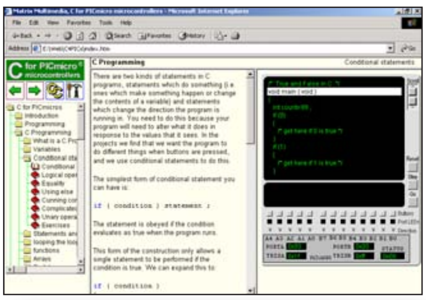


'C' FOR 16 Series PICmicro Version 4

The C for PICmicro microcontrollers CD-ROM is designed for students and professionals who need to learn how to program embedded microcontrollers in C. The CD-ROM contains a course as well as all the software tools needed to create Hex code for a wide range of PICmicro devices – including a full C compiler for a wide range of PICmicro devices.

Although the course focuses on the use of the PICmicro microcontrollers, this CD-ROM will provide a good grounding in C programming for any microcontroller.

● Complete course in C as well as C programming for PICmicro microcontrollers ● Highly interactive course ● Virtual C PICmicro improves understanding ● Includes a C compiler for a wide range of PICmicro devices ● Includes full Integrated Development Environment ● Includes MPLAB software ● Compatible with most PICmicro programmers ● Includes a compiler for all the PICmicro devices.



Minimum system requirements for these items: Pentium PC running, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.
Flowcode will run on XP or later operating systems

FLOWCODE FOR PICmicro V4

FREE with Flowcode V4 (student and institutional versions) ECIO board – a 28-pin reprogrammable microcontroller.

Flowcode is a very high level language programming system based on flowcharts. Flowcode allows you to design and simulate complex systems in a matter of minutes. A powerful language that uses macros to facilitate the control of devices like 7-segment displays, motor controllers and LCDs. The use of macros allows you to control these devices without getting bogged down in understanding the programming. When used in conjunction with the Version 3 development board this provides a seamless solution that allows you to program chips in minutes.

● Requires no programming experience ● Allows complex PICmicro applications to be designed quickly ● Uses international standard flow chart symbols ● Full on-screen simulation allows debugging and speeds up the development process.

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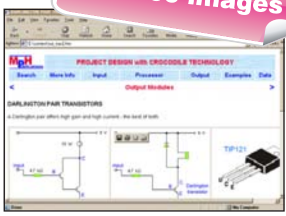

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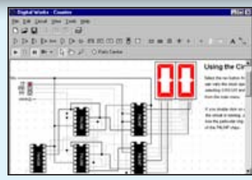

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READOUT

Email: editorial@wimborne.co.uk

Matt Pulzer addresses some of the general points readers have raised. Have you anything interesting to say? Drop us a line!

All letters quoted here have previously been replied to directly

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☆ LETTER OF THE MONTH ☆

RapMan 3D printer

Dear Editor

I read with interest your three articles about the RapMan 3D printer, since I was in the process of building one myself at the time. Discussing the building process, your reviewer said, 'it certainly will not be frustrating'. I believe that you should warn your readers about problems they are likely to encounter with the kit, which were omitted in the review. Otherwise, readers who attempt the kit certainly will find it frustrating.

Here are some of the things to watch out for:

- The instructions don't correspond 100% with the parts supplied. I spent a long time looking for the parts illustrated for attaching the LCD to the control panel and two or three days past before I discovered that they had been assembled already and were in bubble wrap on the PCB.
- The manufacturer is knowingly supplying 'setting bars' with the 12mm holes 2mm away from the correct position. If you don't know this you can easily waste a day and break fragile parts trying to do the impossible. This most definitely is frustrating! Make sure the horizontal distances are okay, and the vertical spacing over the 8mm rods is correct. If necessary, use a tape measure and Pythagoras to check the 12mm rods are true and square.
- Because the instructions supplied with the kit are out of date, you do need to refer to the user submitted notes on the website: **http://bitsfrombytes.com/wiki/index.php?title=User-submitted_notes_on_the_Manual**. This is particularly important when it comes to the heater barrel.
- The instructions for mounting and wiring the cooling fan for the extruder are to say the least unclear. The consensus of opinion expressed by users is that no fan is needed when working with ABS.
- If you have the new extruder head, the extra thickness of MDF renders the suggested measurement for setting the Z-axis depth stop incorrect. You could well crash your extruder nozzle into the base if you don't allow for this.
- The bolt in the top corner of the Z-axis microswitch assembly will probably crash into the corner-block and stop the extruder head homing. It seems strong enough with this bolt removed.
- The head of the M5 bolt on the Z-axis depth stop has to be higher up than the Z-axis microswitch. Make sure this is the case before you select 'Home Tool Head' for the first time, or the side of the bolt will foul on the side of the Z-axis microswitch, and the extruder carriage will carry on trying 'to home' because it is unable to reach the Y-axis microswitch.

I hope this list is helpful. It mentions some of the significant issues, but there will almost certainly be other minor problems to challenge and frustrate assemblers.

I don't want to be too critical of the manufacturers; in many ways it's a good kit, their support is good and their website is good. However, I do feel that a little extra effort on their part could save builders a lot of frustration.

Alan Kidner, by email

Thanks for these tips Alan – most helpful. I've been monitoring the user forum since the product's release, and there has been varied feedback, but overall it's positive. It's an involved mechanical kit, with more than 1600 parts, so yes, it's going to be hard work – but having been through it, I'd still say the results are worth it. Half of the fun is the interaction with other users, not just in the build process but in tinkering with the settings and types of plastics used in the printing process. 3D printing is a cutting-edge technology, and I for one have been delighted to have participated in it at such an early stage.

Mike Hibbett

Pre-programmed project PICs

Dear Editor

I am very interested in constructing the GPS-based frequency reference oscillator, but before I order the PCBs, how do I get hold of IC1, which is a programmed PIC 16F628A (with GPSFrqRF.hex). I believe you do not provide pre-programmed PICs anymore, and if so, what piece of hardware would you recommend I purchase to program the PIC using the software program in your library?

On a totally separate matter, regarding test equipment, I have had no luck finding a kit to build a bench amplifier for signals between DC and 1MHz, which has reasonable response time (rise time) over the bandwidth. Although one can pick up second-hand amplifiers, like the HP 465A relatively cheaply (as I have resorted to), it would be great if *EPE* could consider such a project. Another idea would be an active probe for oscilloscopes, as these come very expensive. I have no equipment (yet) to make my own PCBs, hence my question, and in truth only a limited knowledge about designing circuits from scratch!

Congratulations on the continuance of a great magazine

Andrew, Leaden Roding, by email

EPE *has never provided programmed chips; however, we do work with projects companies to ensue they are available. In this case, the pre-programmed PIC can be purchased from Magenta Electronics. Thank you for your article suggestions, we will investigate these.*

Matt Pulzer

GOT A QUESTION ABOUT *EPE* OR ELECTRONICS?
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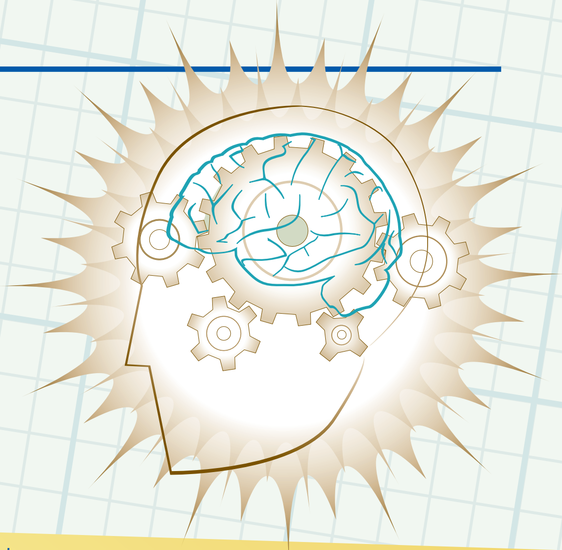
Ingenuity Unlimited

Our regular round-up of readers' own circuits



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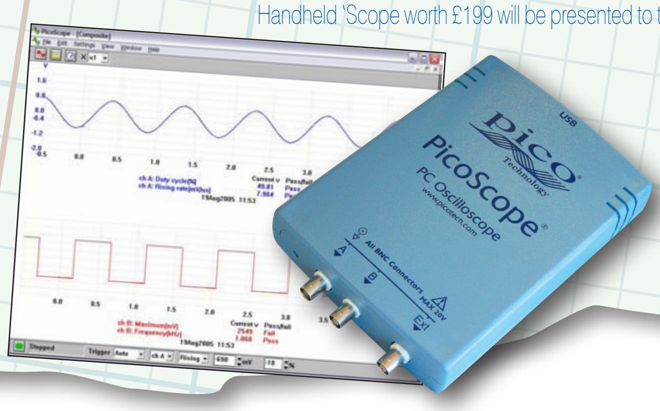


We pay between £10 and £50 for all material published, depending on length and technical merit. We're looking for novel applications and circuit designs, not simply mechanical, electrical or software ideas. Ideas must be the reader's own work and **must not have been published or submitted for publication elsewhere.**

The circuits shown have NOT been proven by us. **Ingenuity Unlimited** is open to ALL abilities, but items for consideration in this column should be typed or word-processed, with a brief circuit description (between 100 and 500 words maximum) and include a full circuit diagram showing all component values. **Please draw all circuit schematics as clearly as possible.**

Send your circuit ideas to: Ingenuity Unlimited, Wimborne Publishing Ltd., Sequoia House, 398a Ringwood Road, Ferndown, Dorset BH22 9AU. Email: editorial@epemag.wimborne.co.uk.

Your ideas could earn you some cash **and a prize** !

Current-stealing Audio Signal Injector – *Fault-finding made easy*

This circuit (Fig.1.) is an audio signal injector, which is used for tracing faults in amplifiers and other sensitive circuits. With the poor joint quality of lead-free solder, this sort of tool will become increasingly necessary.

The circuit is basically the solid-state version of the traditional neon oscillator (see inset illustration). This was often built as a quick-and-easy signal source back in the good old days when you could always steal 100V or so from the equipment under test.

This injector draws only a few microamps, and steals this from the DC level at the test-point. Depending on the DC voltage and audio impedance at the 'test-point', the circuit will inject a signal of a few millivolts at 'middle-audio' frequency.

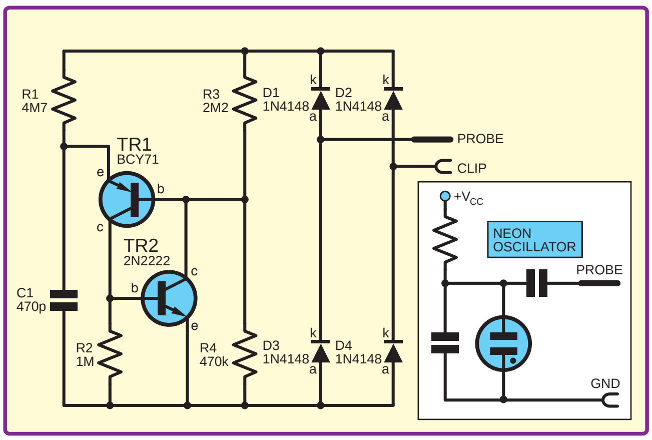
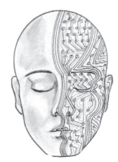


Fig.1. Complete circuit diagram for the Current-stealing Audio Signal Injector

The clip lead has to connect to some voltage level, maybe a ground or Vcc rail. With the component values shown, the injector runs on a voltage difference as low as 3V and as high as 20V DC. Actually, if the voltage difference is more than about 6V you don't need the clip-lead. If the injector has a metal body, you can complete the circuit by touching a suitable voltage level with your finger.

This is an interesting circuit to experiment with. By changing component values the circuit can be made to run on very low (or high) voltages or to inject more power. Other transistors can be substituted, but older 'generic' transistors (eg BC108/178) seem to work best. I suspect this may be because their current gain falls off greatly at such low collector currents.

Walter Gray
Via email



INGENUITY UNLIMITED

BE INTERACTIVE

IU is your forum, where you can offer other readers the benefit of your Ingenuity.

Share those ideas, earn some cash and possibly a prize.

Max's Cool Beans

By Max The Magnificent

I am blown away...

AS usual I am completely blown away by all of the 'stuff' we are discovering about life, the universe, and everything – but particularly about life and the way in which everything works. For example, I just read a brilliant article that blew my socks off, describing how complex life forms (like me) can evolve in a single generation!

Do you recall my review of the book *Wetware: A Computer in Every Living Cell* (see *EPE*, Jan '10)? If so, you may recall that this tome starts by considering how a single-cell creature, such as an amoeba, can lead such a sophisticated life – how it hunts living prey; responds to light, sound, and smell; and displays complex sequences of movements – all without the benefit of a nervous system.

The book then takes us onwards and upwards through the way in which single-celled creatures of this ilk can communicate with each other (by generating proteins and passing them around), to simple multi-celled creatures, all the way to mega-complex beasts like you and me (particularly me, of course [grin]). Along the way, we discover how single-cell and multi-cell entities can evolve over time – but we are always reminded that this evolution takes place over LONG stretches of time.

I love this stuff, which explains why I found the article 'Why Genes Aren't Your Destiny' (which appeared in a recent issue of *Time* magazine) so incredibly amazing, because it explains how complex beasts like ourselves can evolve in as quickly as a single generation.

DNA

Here's a question for you. We all know that every cell in our body contains the same DNA, so why are individual cells (skin cells, muscle cells, nerve cells) so different? The answer is a collection of 'molecular switches' called epigenetic marks that are attached to the DNA. These switches, which cause different genes to turn on or off, conceptually sit 'on top' of the genome (hence the prefix 'epi' meaning 'above').

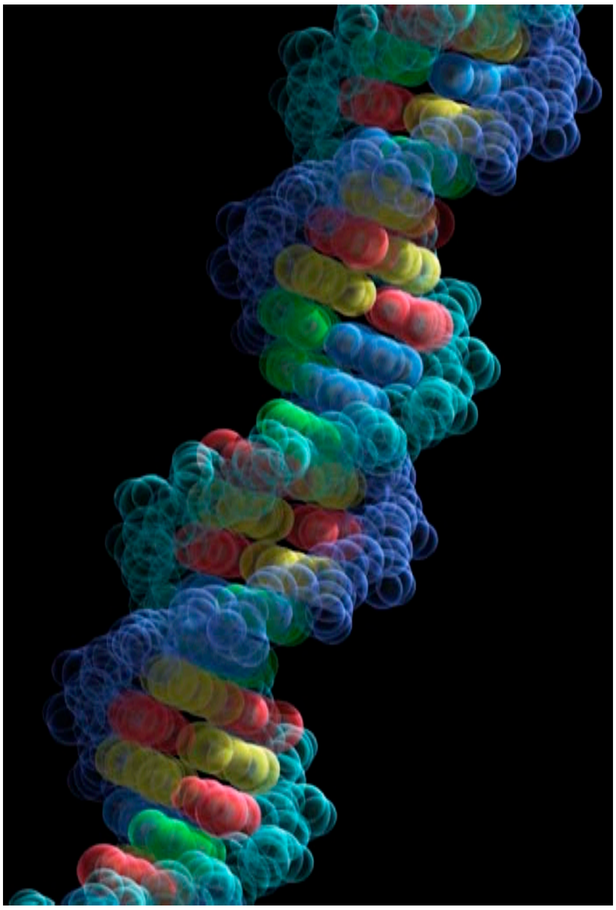
The point of all this is that there's long been a debate as to the relative importance of 'nature-versus-nurture', which provides a convenient catch-phrase for the roles played by heredity and environment in human development. The new field of epigenetics goes beyond this – we now know that lifestyle choices like smoking and eating too much can change our epigenetic marks, thereby affecting the way in which our genes express themselves.

Human genome

More importantly, these changes in our epigenome can be passed down to our children and to their children. And how much do we really know and understand about all of this? The answer at this time is almost nothing. Remember the *Human Genome Project*? This determined that the human genome contains around 25,000 genes, and we know (or rather we don't know) just how complex this is. Well, if we visualize the complexity of the genome as being a drop of water, then we can visualize the relative complexity of the epigenome as being a mug of the stuff (analogies are always suspect, and this one is doubly so because I just made it up, but I'm sure you get my drift).

Can we harness the power of epigenetics for good, or will we mess things up like usual? I tell you what, you should read the full article and then let's put our heads together and ponder the possibilities. You can read it online at the *Time* website (**www.time.com/time/health/article/0,8599,1951968,00.html**), although for some unknown reason the title of the online post *Why Your DNA Isn't Your Destiny* is slightly different to the print version.

Seriously, I would love to hear your feedback on all of this, so please feel free to contact me at **www.TechBites.com/MaxMaxfield** to tell me what you think.



A model of a strand of DNA

Check out 'The Cool Beans Blog' at www.epemag.com

Catch up with Max and his up-to-date topical discussions

Net Work

Alan Winstanley

Almost always on

An ongoing problem on my home network suggested a potential failure with my wireless router, or maybe my broadband connection. I'd noticed how web sessions would lock up unexpectedly during, say, checking my online banking, and I would have to log in again. It was as though I had been disconnected and the offending website no longer recognised me. This has all the signs of a hardware or broadband problem, and some checks with my excellent broadband provider soon shed light on the matter: a log of the previous fortnight's activity confirmed that I was indeed disconnecting every five or ten minutes!

I investigated further by looking at my router's settings. In order to access a router's configuration, in Windows XP, Vista or Windows 7, open a Run dialog box (Windows Key + R) then type **cmd** to open a DOS prompt. Then type **ipconfig** to display the local network configuration and look for 'default gateway'. This is the IP address of your router (not your IP address seen by the rest of the world). Try **ipconfig**/? for more options.

Typing that IP address (eg 192.168.0.1) into your web browser will open your router's configuration pages. You will need a username/ password combination; the defaults are usually admin/ admin, admin/ password, or maybe admin/1234. They may perhaps be recorded helpfully on a label on the underside, or somewhere in the manual. Also look around the router's setup to see what, if any, logs are available. In my own case, my excellent ISP, Swift Internet, agreed to monitor the connections logs if I changed the network setup at my end: I have failed to find any useful software that would monitor my connections – if you would like to share any suggestions, please let me know.

Just like troubleshooting an electronics project, it's best to eliminate the obvious things first, so I swapped the ADSL microfilter and wiggled the connections to overcome dust and tarnishing of the contact wipers and generally ensure everything was hooked together soundly. This made no difference to my disconnection problem, so the next move was to try a different router. And if that would not cure the problem, I would nervously have to think about reporting a faulty phone line connection: BT charge for visits that fail to reveal any BT-related fault, so that is a last resort.

For testing purposes, I sourced the smallest, cheapest single port wired router I could find, in the shape of a £25 ZyXEL Prestige 660R-D1 ADSL2+ Router, which I hooked up to a spare laptop. When installing a router on simple home installations, it's often only necessary to enter the ADSL username and password via some configuration pages and accept the default settings, but sometimes you may need to alter some parameters: check your broadband supplier's setup data. My little Zyxel fired up immediately, and after a 24-hour test session, the result came back from my ISP – a good, solid connection with no interruptions!

A Tenda moment

It seems to me that the average life of a router is maybe 30 months before they fail: maybe an Ethernet port goes down or the power supply fails or, as in my example, they don't maintain a stable connection for any length of time. I saw no point in spending £70 retail on a shrink-wrapped WiFi router that will only end up in the rubbish skip, so I scouted around online for something more sensibly priced. I stumbled upon a 802.11n router with combined switch and firewall from the Chinese manufacturer Tenda (**www.tenda.cn**). Their 300D Wireless-N router is available at the time of writing from **www.ebuyer.com**

This neat little unit is half the price of a more popular brand, so I can forgive the slightly 'Chinglish' dialogues. It utilises MIMO (Multiple Input/Multiple Output) technology for improved transmission range – the manufacturers claims an eight-fold improvement over 802.11g. The Tenda 300D provides a main SSID, as well as a secondary SSID: effectively, two wireless network IDs become available.

I sourced a matching Tenda 802.11n USB dongle for a nearby networked PC. After setting the ADSL username and passwords, the router logged on and started earning its keep instantly. The Tenda USB dongle also installed without a hitch, and the software applet is perfectly adequate, though I had to add a Windows shortcut to the Startup group to enable the connection when booting. Security issues were addressed with appropriate wireless encryption keys, and the whole network seems sprightlier as a result of the upgrade to 802.11n.

A number of sources seem to be nothing less than delighted with this brand, and a friendly computer technician agrees that Tenda's technical support is hard-working and earnest, with no language difficulties that cannot be overcome. It is worth adding Tenda to your router shopping list in the future, especially in these cash-strapped times.

Overlooked

One issue that arose was an overlooked Windows 98 PC that runs some financial software elsewhere in the building, accessed with VNC software. Windows 98 barely supported the basic and insecure WEP (Wireless Encryption Protocol) anyway, let alone the higher level WPA-PSK standard now deployed. In the past, third party software could allow WPA-PSK to operate in the Windows 98 environment, but this software is no longer available. Plus, there was the problem that a modern USB 2.1 WiFi dongle has no W98 drivers anyway. So how to connect a remote W98 machine to the upgraded network?

The answer was to use mains-borne networking instead. Probably the easiest piece of hardware I've ever installed (apart from a toaster), Develo Homeplug is a mains adaptor which uses one router port to superimpose the network onto the ring mains; a similar mains adaptor near the remote PC provides a convenient Ethernet port. This system solved the problem immediately, but there are some caveats which I'll discuss in more detail on my bonus *Net Work* column at *EPE* Online at **www.epemag.com**.

You can Email me at **alan@ epemag.demon.co.uk**

Tenda is a less well known brand of router and networking hardware that is worth considering: buy online from IT vendors.

PCB SERVICE

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